WORKING PAPER

OAST

SPACE & NUCLEAR R&T PROGRAM & SPECIFIC OBJECTIVES

FY 1975

N78-78438

(NASA-TM-79767) SPACE AND NUCLEAR R AND T PROGRAM AND SPECIFIC OBJECTIVES (National Aeronautics and Space Administration) 322 p

Unclas
00/81 29401

WORKING PAPER

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY
SPACE AND NUCLEAR PROGRAM
SPECIFIC OBJECTIVES
DOCUMENT APPROVALS

Robert E. Smylie DATE 3/25/74

R. E. Smylie
Deputy Associate Administrator
(Technology)

George W. Cherry DATE 3/27/74

G. W. Cherry
Deputy Associate Administrator
(Programs)

DATE

Gen. Holloway
Acting Associate Administrator

PREFACE

This document is intended to be a working document that provides the foundation for more meaningful objectives including quantifiable targets that meet needs and opportunities. The objectives and targets detailed in this document represent a continuing OAST movement to make the program more result-and accomplishment-oriented, and thus improve our ability to advocate research and technology.

A more quantifiable set of objectives will also help to bring about improvements in our management such as:

- o Improve our ability (Centers and Headquarters) to evaluate the technical feasibility of programs and weigh the adequacy of our planning
- o Improve program control in Headquarters and at the Centers by providing each management level a better idea of what he or she is supposed to accomplish and how to keep track of progress
- o Improve Headquarters - Center relationships by providing a better basis for how each Center's RTOP fits into the overall program plan

The targets for many of our objectives have been selected to tax our imagination and ingenuity. They may not all be accomplished within the specified time frame nor will all performance goals be technically achieved. The research and technology process is characterized by a tortuous unpredictable path that can result in failure. A target cannot be a guarantee of success. The target represents our <u>best</u> technical and schedule judgment as to what can be accomplished.

Our management philosophy and system recognizes the reality of the R&T process and retains the flexibility to alter and change a target as better information becomes available. However, we also recognize that the researcher is at his best, and fired up with enthusiasm, when he or she is seriously committed to achieving a set of targets. The ultimate purpose of this document is to achieve that commitment at all levels from the bench to the Associate Administrator. It is intended that this document or appropriate parts of it be disseminated to all levels of the OAST organization simply stated, the following principles represent the basis for our management philosophy:

1. Common objectives, visible to all OAST management levels, will insure a unity in our actions.

2. The greater the focus on desired results the more likelihood of achieving them.

3. Participation by all levels (AA to the bench scientist) in establishing objectives and targets will motivate people at all levels to achieve them.

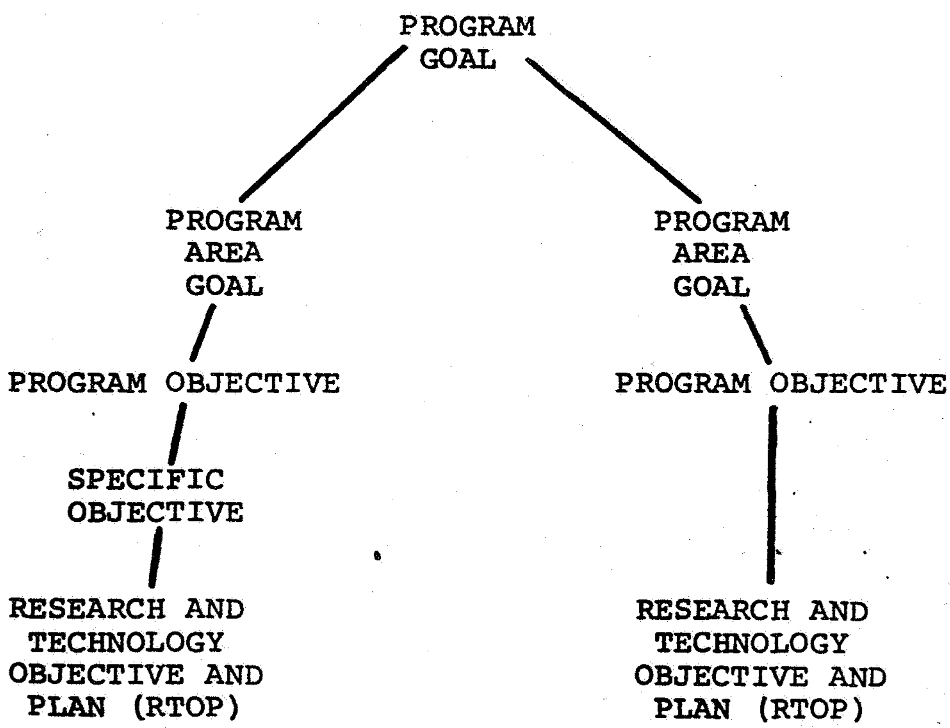
4. Our progress can only be measured in terms of the results we strive to obtain.

CONTENTS

INTRODUCTION

In October of 1972 Mr. Jackson requested that the OAST management system be reexamined with special emphasis on the work breakdown structure and program objectives. A committee chaired by Dr. Himmel surveyed the management system and concluded that the work breakdown structure could be made simpler and that the program objectives need to be strengthened. In addition, the RTOP process was briefly reviewed and it was concluded that improvements in the process and content of the RTOP was indicated. This document presents a significant enhancement in program objective and specific objective content as well as a more consistent, simpler work breakdown structure.

This document provides a program goal and objective structure that parallels the work breakdown structure. In a very real sense it is a hierarchical structure that relates each and every Center RTOP, its manpower and funding, to a set of objectives that support our overall program goal. Our hierarchical structure, depending on type of program, takes on one of the following forms:



The single space and nuclear program goal which supports the nation's needs in space and nuclear is broken down into three program area goals. They are:

1. R&T Base
2. Systems and Design Studies
3. Systems and Experimental Programs

Each of these program area goals is further broken down into program objectives, and in many instances program objectives are further broken down into specific objectives. The division of some program objectives into a lower level of specific objectives is dependent on the type of program but more importantly by the need to provide a level of quantification to the program that would make Center RTOP planning and negotiations more meaningful.

This document provides our goals and objectives in sufficient detail to allow the Centers to participate in the establishment of a set of meaningful technical performance targets that fulfill recognized needs. This document represents the principle justification for all activities funded by OAST and conducted at the Centers. Center decisions concerning RTOP planning and implementation are to be made within context of the structure provided herein. Centers are expected to view their OAST funded activities in terms of how they fit into the overall plan for each objective (program and/or specific) because each objective responds to recognized needs.

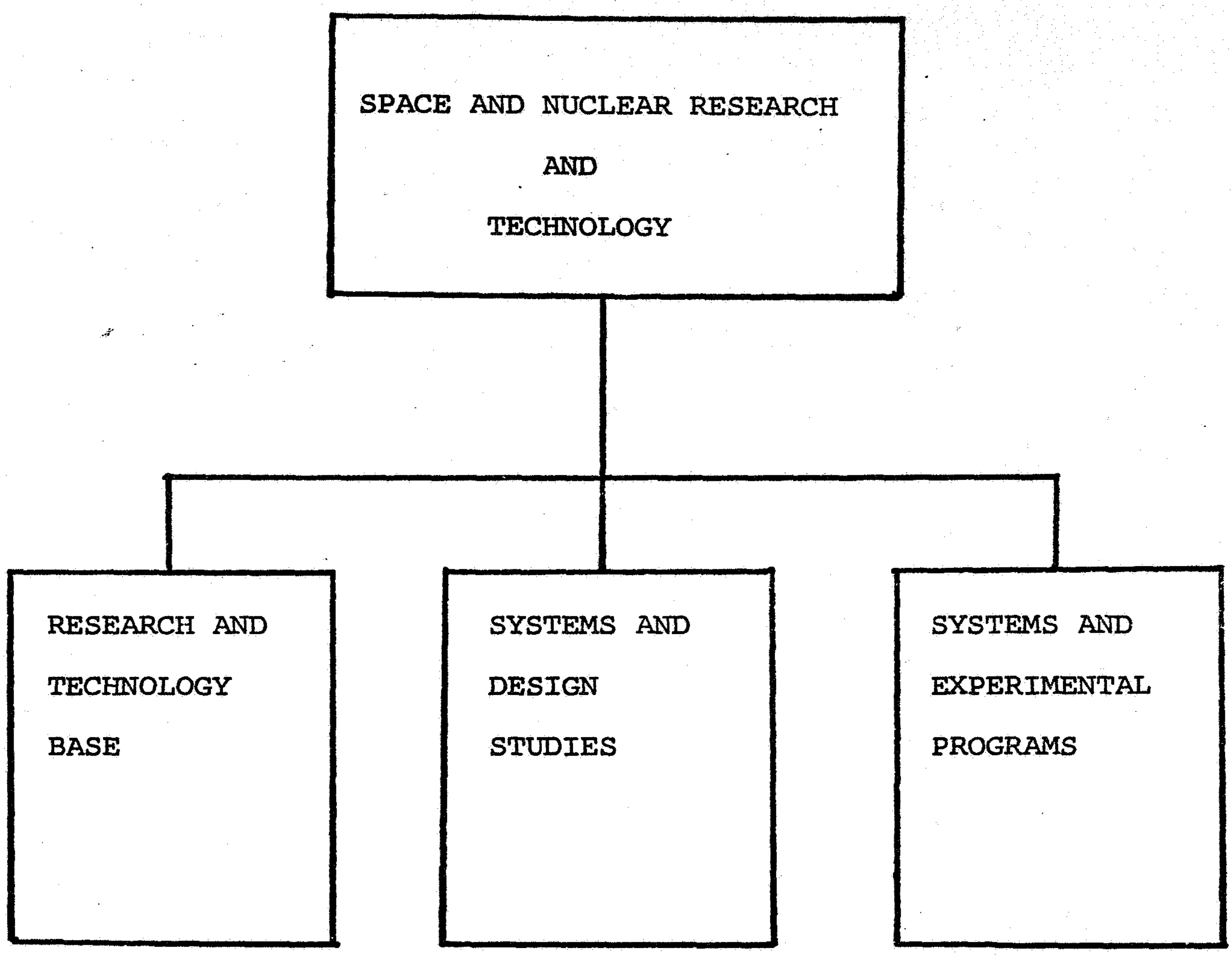
We recognize that the program is advanced research and technology. The input to the program is the capable effort of highly qualified people, using specialized equipment and facilities, doing theoretical, analytical and experimental work. The output is new technical knowledge. The purpose of the program is the output, new technical knowledge. The output is created by OAST primarily for application by others. Further, each bit of the new technical knowledge is useful to many people for many different applications. This multiapplicability aspect of our program output is fundamental to the program structure and the management of the program.

In creating new technical knowledge, which, to repeat, is the output of our program, it is recognized that there are many technical areas, within the broad charter of nuclear and space, where we find interesting and challenging opportunity to do creative work. These opportunities are an invitation to each and everyone to work in self-chosen areas. But to do only so is not necessarily advisable or permissable. Why not? Simply because to work all those technical problems and those technical areas that are the first choice of each professional (it is granted that there is evident opportunity to create useful new technical knowledge) while in addition having effort under way in our program to create needed new technical knowledge, would require program resources, or dollars, beyond those obtainable.

In our program content, we cannot just be guided by what, as the research's and technologist's interest would suggest, is desirable. We must constrain the program content by what is advisable, as the need for new technical knowledge suggests. This advisability versus desirability aspect of our program output is fundamental to the program structure and the management of the program. It is the reason for establishing meaningful objectives upon which to base our RTOPs. The objectives established herein are responsive to the National needs and specific areas of focus that OAST has selected as being responsive to these needs. This response is the advisability aspect of our program.

SPACE AND NUCLEAR R&T WORK BREAKDOWN STRUCTURE

LEVEL I & II



LEVEL II PROGRAM
AREAS

PROGRAM GOAL

The space and nuclear research and technology program goals can be succinctly stated as:

> Provide improvements and advancements in the engineering sciences and technologies used in the systems required to transport, protect, power, control and communicate with the scientific instruments needed to achieve the objectives of the other NASA program offices.

The activities directed towards this goal support the following three NASA goals:

1. Provide More Effective Means for Utilization and Advancement of Capabilities in Space While Reducing the Cost of Space Operations.

2. Increase Scientific Knowledge and Understanding Through Exploration of the Earth's Environment, the Planets and the Universe.

3. Expand the Practical Application of Space Technology.

The OAST Space and Nuclear Research and Technology goal is intended to complement the research and technology activities of the other Program Office research and technology that support the above goals. For example: while OSS directs its efforts on research, on space, and those of OA are directed towards experimental application work from space, the OAST programs are directed towards future systems required to enable the conduct of activities in space.

The space and nuclear program compromises several thrusts or emphases towards the needs of the NASA space program. It concentrates on advancements in the engineering sciences and technologies needed to achieve the NASA objectives. These advancements are grouped under the following broad heading of needs.

Exploitation of Space

There are several subdivisions of this part of the program, each pursuing complementary approaches toward cost reduction.

1. Completion of the shuttle technology support program aimed at assisting in the development of low cost transportation to low Earth orbit.

2. A technology program directed toward reducing the cost of spacecraft and payload systems that the shuttle will transport.

3. Technology that attacks the problems of how to store, transmit and analyze massive amounts of data in the most economical manner.

Space Exploration

Whereas with the advent of the shuttle transportation system NASA will be in a position to trade performance and weight for cost reduction for operations in Earth orbit, for missions to the planets performance and weight of spacecraft systems are still at a premium. The technologies that respond to the needs under this title are driven primarily by the demands for improved performance required for such missions. These requirements stem primarily from the great distances involved (up to 6 million Km to Pluto), the high propulsive energy required to accomplish them, and the high velocities involved as well as long trip times.

Civil Needs

An added emphasis of the OAST Space Program is the application of technology to civil energy needs. OAST is investigating the application of technology to local pollution detection and monitoring, and the application of technology in power and propulsion to the problem of energy conversion and conservation.

These needs and the objectives associated with them are reflected in an OAST program which is structured into three areas, i.e., Research and Technology Base, Systems and Design Studies, and Systems and Experimental Programs. This permits the logical evolution of an interesting idea into a verified operational concept within a single coordinated program. The program areas are described as follows:

R&T Base is the basic research, discipline R&T and systems R&T which is forward looking in its potential application to the broadband of NASA goals in space and encompasses all the traditional space disciplines.

Systems and Design Studies are conducted to provide the necessary analytical results which permit the successful transfusion of the technology developed under the R&T Base into Systems and Experimental Programs.

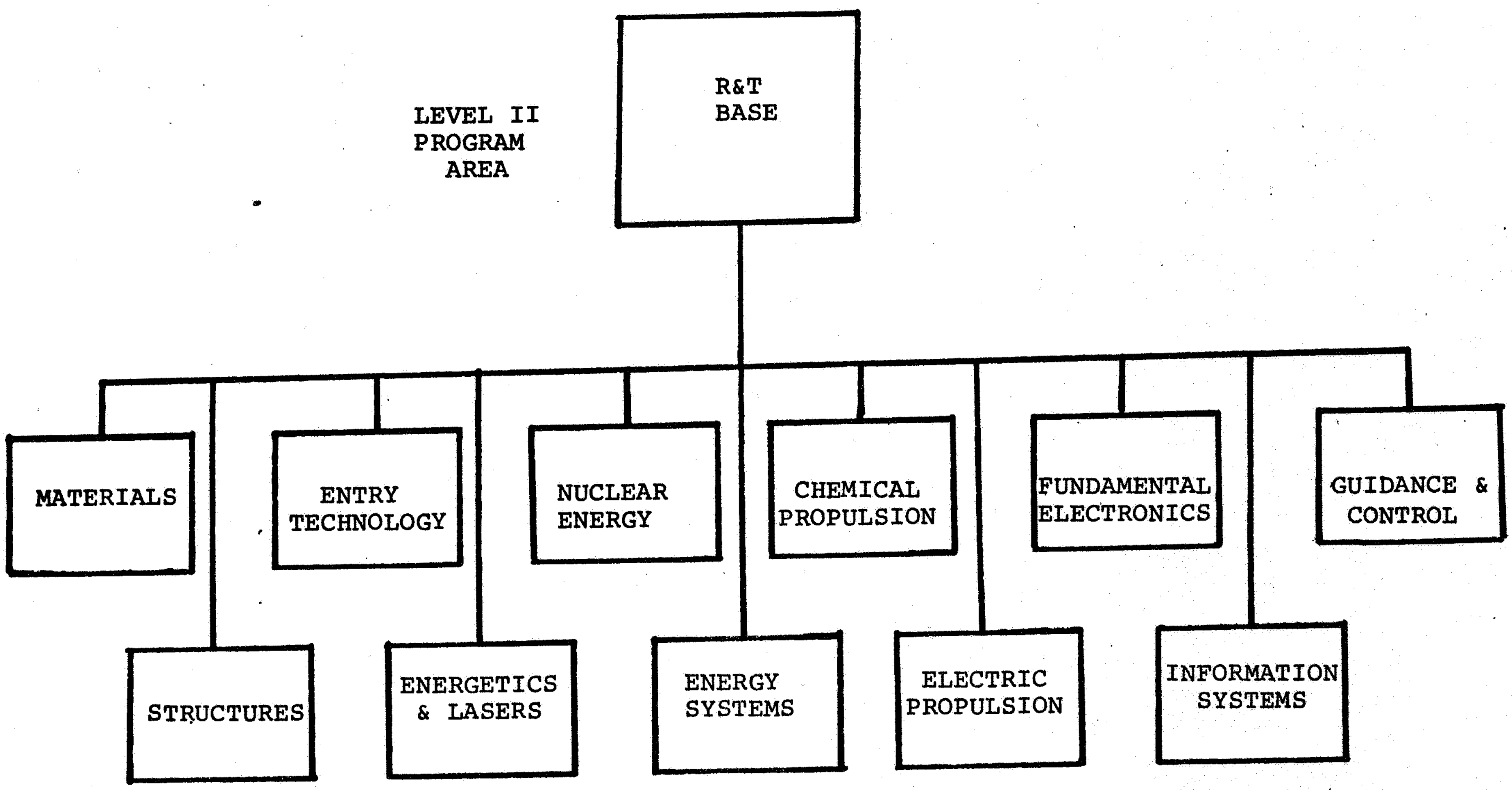
Systems and Experimental Programs are aimed at verifying the technical readiness of technological concepts proven feasible in a design study when it is necessary to go beyond component technology to permit more informed development risk decisions. The systems programs are used to develop the technology applicable to a specific type of system (including multi-disciplinary systems) while the experimental programs are those activities that involve design, fabrication, and testing of a multi-disciplinary concept in a realistic environment.

OAST SPACE MATRIX - FORMAT

NASA EMPHASIS	GAIN FUNDEMENTAL SCIENTIFIC KNOWLEDGE				ROUTINE & ECONOMIC SPACE TRANSPORTATION & FACILITIES				EXPAND PRACTICAL APPLICATION OF SPACE TECHNOLOGY			
OAST EMPHASIS	ENG'ING SCIENCE & INNOVATION		DEEP SPACE EXPLOR SYSTEMS		LOW COST TECHNOLOGY FOR EXPLOITATION OF SPACE				TECHNOLOGY FOR CIVIL NEEDS			TECH FOR MILITARY NEEDS
OAST FOCUS / OBJECTIVES	BASIC RESEARCH	INNOVATIVE TECHNOLOGY	S/C & ENTRY SYSTEMS TECH	HIGH ENERGY PROP TECH	SHUTTLE TECHNOLOGY	LOWER COST & HIGH PERF EFFECTIVE SYS	SHUTTLE EXPLOITATION TECHNOLOGY	USER INTERACT INFO SYSTEMS & MONITORING	SOLAR ENERGY	ENERGY CONV & CONSERVATION	CIVIL SYST TECHNOLOGY	DOD SUPPORT
LISTING AND RELEVANCE BY PROGRAM AND SPECIFIC OBJECTIVES. A DISPLAY OF LEVEL III AND IV OF THE SPACE AND NUCLEAR WORK BREAKDOWN STRUCTURE												

SPACE AND NUCLEAR R&T WORK BREAKDOWN STRUCTURE R&T BASE

LEVELS II & III



LEVEL III PROGRAMS

PROGRAM AREA GOAL

The program area goal is to:

> Provide fundamental knowledge and understanding in the disciplines associated with space and to apply this knowledge to establish the feasibility of a concept, or provide new techniques and design data.

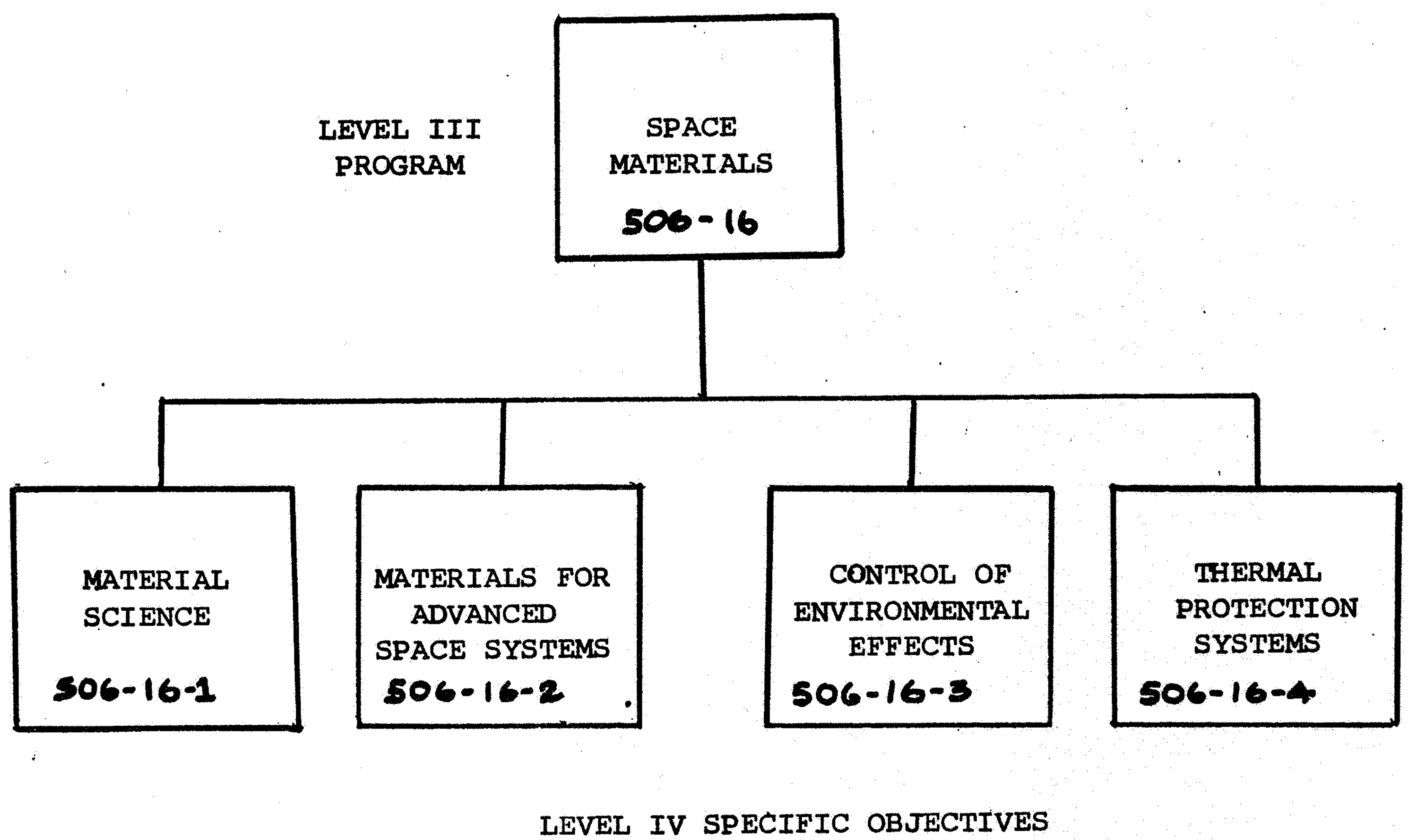
This goal involves state-of-the-art advancements in the following disciplines:

- o Materials
- o Structures
- o Entry Technology
- o Energetics and Lasers
- o Nuclear Energy R&T
- o Chemical Propulsion
- o Electric Propulsion
- o Fundamental Electronics
- o Information Systems
- o Guidance and Control

The R&T Base is primarily single discipline research and technology in the above eleven discrete engineering disciplines. It is both basic research and applied technology. It is largely laboratory work as compared to flight work. It is synergistic in that it has multiapplicability to many requirements of space science and applications as evidenced by the matrix program planning process used by OAST. It is carried out largely in-house.

It is work that is unparalleled in the U.S. It is the data base from which springs new ideas for development in the future. Without the R&T Base and planned, the opportunities for new ideas would deteriarate. Industry funds very little work in these discipline and the DOD activities are very mission oriented and of minimum relevance in many of these disciplines.

SPACE MATERIALS WORK BREAKDOWN STRUCTURE



SPACE MATERIALS
RESEARCH AND TECHNOLOGY

Program Objective

Provide, through state-of-the-art advancement, materials for highly efficient, low cost spacecraft structures, thermal protection systems, and propulsion and power systems for future orbiting and planetary vehicles, and support the development of the Space Shuttle with unique expertise and facilities. Accomplish the following:

- o Provide concepts for the synthesis of new advanced materials by improving the basic understanding of their nature and behavior.
- o Provide reliable lightweight insulations for use on reentry vehicles up to 2800°F.
- o Increase the life of thermal control coatings for both early orbiting and planetary systems from one to three years.
- o Provide heat protection technology for each orbital missions and planetary exploration.

The NASA materials R&T program has made significant contributions to the high performance and reliability of manned and unmanned spacecraft systems. Future targets will provide the means to reduce the costs and further improve the reliability and lifetimes of all space transportation systems.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	246	226	226	230	210	210

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D	4,773	4,150	4,501	4,710	4,675	4,750
IMS	1,856					
TOTAL R&D	6,629					
R&PM Resources	4,726					
TOTAL VALUE	11,355					
EST. NET COSTS	4,123					

2/20/74

TITLE: Materials Science

TYPE OF SPECIFIC OBJECTIVE: XX DISCIPLINE ____
STUDY ______ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Materials Program - James J. Gangler

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To gain greater understanding of the electronic, molecular and atomic structures of materials, relating these to useful materials properties, and using the relationships as a guide toward obtaining new or improved materials; achieving this through the following:

Targets:

- o Expand our understanding of surface properties and surface-environment interactions from the molecular to the atomic level, and determine their effects on material properties.

- o Determine the basic relationships between the electronic and defect structures in semiconductors for such purposes as increasing the efficiency of gallium arsenide junction and Schottky barrier solar cells from 13 tp 20 percent by 1976.

- o Extend, by 1977, our understanding of adhesion, friction and wear from the current qualitative state to a quantitative basis so as to eliminate present costly and time-consuming empirical approaches to the selection of materials for bearings, gears, seals, and lubricants.

- o Establish, by 1977, whether the solution softening and grain size effects previously observed in refractory metals also apply to iron-base and nickel-base alloys. Use these effects to guide a program aimed at improving the strength and toughness of these latter materials.

- o Determine by 1978, the molecular parameters that control the long time behavior of elastomers used for such applications as sealants.

- o Improve our understanding of the properties of superconductors for the purpose of (1) increasing superconducting transition temperatures above $40^{o}K$ by 1979, and (2) for improving the sensitivity and spectral response of far-infrared sensors.

- o Establish an understanding of the defect properties and the mechanisms of interaction of radiation with dielectric films and insulators for the purpose of achieving long-life micro electronics by FY 79.

APPROACH:

Fundamental materials research in NASA is conducted primarily at the Lewis Research Center with one-half of the resources of this objective. ARC, LaRC, JPL, and MSFC consume the remainder. Emphasis is on understanding why materials behave as they do when subjected to mechanical and thermal stresses, and chemical, radiation, electrical, and thermal environments. Such understanding can lead to new and improved metals, polymers, ceramics, dielectric films, and composite materials.

- o The unique ARC high resolution microscope will be utilized to study surface-controlled properties of materials. The studies will range from the interaction of foreign atoms and molecules on solid surfaces to growth mechanisms of thin films. A near term target will be to explore the corrosive nature of liquid fuels on container materials and will utilize several concurrent approaches: (1) static metal coupon-fuel corrosion tests to determine corrosion rates, (2) physical analysis procedures to measure film formation, passivation effects, and H_2 diffusion rates and (3) plane-strain fracture tests to ascertain corrosion effects.

- LaRC is conducting basic property studies that are fundamental to improved solar cells, pollution-gas sensors, molecular reactions and catalysis. Solar cells could have improved efficiency and high temperature power production by using GaAs with reduced surface recombination rates. Ion-implantation will be employed to deposit controlled amounts of dopants on these cells in order to lower surface recombination rates. The technique will also be used to vary impurities in solar cell junctions in order to determine their effects on junction efficiency. JPL is investigating an approach which eliminates the junction and surface recombination problems in GaAs. The technique is the metal-semiconductor barrier or Schottky barrier solar cell.

- High temperature superconductivity research consists of a closely coordinated effort between experimental and theoretical programs at JPL and theoretical programs elsewhere which are supported by NASA. The central concept involves the interaction of metallic electrons with a polarizable medium, theoretically producing an organic superconductor or organiz metal. As a near term target, two mechanisms for achieving organic superconductivity will be investigated: (1) Excitonic superconductivity involving filamentary structures, which will be modeled by computer techniques, and (2) non-excitonic superconductivity involving metastable, three-dimensional structures of electron-rich and electron-poor molecules. Transport and X-ray measurements will be used to verify the metallic nature of the organic metals. A longer range target will be a program to determine a class of dielectric functions which lead theoretically to high transition temperatures, and then to synthesize material structures having such dielectric functions.

- Basic studies at LeRC in physics and chemistry of solids are directed at three areas. For metal matrix composites the emphasis is on gaining an understanding of the deformation processes and chemical reactions with the environment that occur at the fiber-matrix interface. Studies of battery separator materials for alkaline batteries are focused on gaining an understanding of the roles of the various components ents in order that longer battery life can be obtained. The third area is on the hot corrosion of turbine bucket alloys. The studies are aimed at gaining understanding of the chemical mechanisms involved and the particular roles of salt and airborn sulfur compounds. The information gained should guide alloy development as well as coating formulation for application to aircraft, marine and land based gas turbines.

- JPL is conducting basic studies of the defect properties of silicon-dielectric interfaces in a closely coordinated effort with another NASA program aimed at long-life microelectronics. The studies focus on relating the chemical and defect structure of the interface to failure mechanisms induced by electrical, thermal and radiation stress. Measurements involve tunneling, time-dependent breakdown, surface states by C-V analysis, high energy irradiation, secondary ion mass spectrometry and high resolution x-ray photoelectron spectrometry. In the near term approach, investigations will be carried out on SiO_2/si and $AL_2O_3/SiO_2/Si$ interfaces which are consistent with the practice of semiconductor industries.

- Basic studies on the adhesion, friction, and wear properties of materials under conditions of touch contact and sliding and under controlled environments are being conducted at LeRC in one of the nation's best bearings, seals and lubricants laboratories. Such research tools as Low Energy Electron Diffraction (LEED), Auger emission spectroscopy analysis, field ion/field emission microscopy, and a scanning electron microscope will be employed to study the atomic and molecular structures of material surfaces. Unique features of this equipment permit their use during dynamic experiments. Studies on the molecular changes in organic lubricants will employ infrared spectrocopy and interferometry.

- Hardness measurements on Molybdenum-base alloys have shown that softening can be related to valence electron/atom ratio of the solutes. Niobium-base alloys do not show softening when compared to high-purity outgassed Nb. Iron-base alloys show softening with all solutes. These results suggest the possibility of more than one softening mechanism. In a near term target magnetic susceptability will be measured to determine the fundamental basis for the softening phenomena. Creep rates in unalloyed Ni, Ni-Cr and NiFe will also be measured at different grain sized, and temperatures.

- The ultimate properties of high and low molecule weight elastomers will be determined as a function of test rate and temperature. In addition, tear properties and lifetime in creep, stress relaxation and dynamic fatigue will also be determined at several temperatures. Disulfide containing polymers will be subjected to UV radiation while under stress or strain in order to determine the interaction of scission reactions with mechanical relaxation in crosslinked polymers. Dynamic response parameters and fatigue endurance of polyester films of varying morphology will be evaluated at various rates and temperatures.

Major milestones of Materials Science are:

Mid FY 75 - Optimization of GaAlAs-GaAs cell.

Mid FY 75 - Completion of PEN 2,6 - oxygen studies and application to pollution sensor.

Mid FY 75 - Theoretical model of excitonic superconductor and synthesis of Pt compounds.

End FY 75 - Measurement of magnetic susceptibility in Mo, Nb, and Fe base alloy completed.

Mid FY 76 - Tear Tests completed on elastomers prepared from low molecular weight precursors.

End FY 76 - Determination of major factors contributing to radiation-hardened dielectric films for microelectronics.

End FY 77 - Model of defect mechanisms at silicon-dielectric interfaces.

NEED AND RELEVANCY

Materials Science directly supports the Materials Program. This work is also of primary relevance to the specific OAST focus of basic research shown in the space matrix.

Materials Science provides the fundamental understanding of why and how materials behave when subjected to a range of mechanical, thermal, radiation and chemical environments. Achieving a better understanding of the properties of metals, dielectric films, polymers, ceramics, and composite provides technologists a rationale for improving or devising new engineering materials. As we approach the limits of melting points, and mechanical and chemical stability, an understanding of the atomic and molecular structures of matter can often provide alternate solutions for the demands of the designer. When unforeseen problems arise a knowledge of materials properties will suggest alternates.

We therefore expect that a broad, continuing program on fundamental materials research will support NASA's objectives. We also expect that the knowledge gained from this objective will also benefit NASA's aeronautical programs and civil needs.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	68	56	63	72	72	72
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1598	1625	2026	2100	2150	2200
IMS	805	850	850	850	850	850
TOTAL R&D	2403	2475	2876	2950	3000	3050
R&PM Resources	1949	2020	2000	2000	2000	2000
TOTAL VALUE	4352	4495	4876	4950	5000	5050

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man-Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man-Power	BEST ESTIMATES FY 76 Net $ (K)	BEST ESTIMATES FY 76 Man-Power
502-01-01, Surface Physics & Chem.	ARC	160	8	110	8	110	8
502-01-02, Physics & Chem. of Solids	ARC	36	2	35	2	36	2
	LeRC	140	22	140	21	150	21
502-01-03, Mtls For Electronics	JPL	245	5	200	5	245	7
	LaRC	146	11	170	12	150	9
	MSFC	10	3	-	-	45	3
502-01-04, Inter-disciplinary Lab.	LeRC	600	1	600	1	600	1
502-01-05, Non Metallic super-conductors	JPL	41	3	200	3	235	4
502-01-06, Atomic Structures	LeRC	45	2	45	2	60	3
502-01-07, Fun-damental Lub.Mat.	LeRC	50	9	-	-	-	-
502-01-08, Visco-elastic Polymers	JPL	125	2	125	2	280	5
TOTALS		1598	68	1625	56	2026	63

c. Crosswalk Resource

1. 100% of resources of primary relevance to the "specific OAST focus" of basic research.

2/20/74

TITLE: Materials for Advanced Space Systems

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE ___ STUDY
___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Materials Program - Joseph Maltz Joseph Maltz

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To establish and demonstrate the technology of advanced materials and manufacturing processes for future space vehicles, including their propulsion and power units. The materials to be studied include lubricants and bearing materials, optical materials, and composites.

Targets:

- o Extend capability of 500 psia LOX sealing systems from single start to 100 starts by 1975 for service in reusable spacecraft propulsion units. This will be accomplished by incorporating improved graphitic materials into new self-acting lift-pad seals. Improve purged seals to reduce helium inventory for turbopump by 90%.

- o Complete evaluation during 1975 of the utility of the chemical vapor decomposition technique for reliably bonding aluminum to graphite fibers, as part of the technology needed to provide advanced structural composites for vehicles such as the space tug.

- o Identify, during 1975, degradation mechanisms of high energy laser window materials and define program to produce materials for long time, continuous operation.

- o Demonstrate, by 1976, 100-cycle life of actuator control system bearings exposed alternately to $600^{o}F$ reentry and an orbital environment.

- Extend, by 1977 our understanding of adhesion, friction and wear from the current qualitative state to a quantitative basis so as to eliminate present costly and time-consuming empirical approaches to the selection of materials for bearings, gears, seals and lubricants.

APPROACH:

This objective covers a variety of tasks involving such disciplines as metallurgy, ceramic engineering, polymer science and lubrication engineering. The activities are carried out at the Langley and Lewis Research Centers. Langley is conducting investigations that include analysis and evaluation of materials combinations under complex fabrication and service conditions. Lewis is concentrating on lubricants, laser materials and high temperature alloys.

Basic studies of the adhesion, friction and wear properties of materials under conditions of touch contact and sliding and under controlled environments are conducted at LeRC. Low energy electron diffraction (LEED), Auger emission microscopy and scanning electron microscopy allow study of material surfaces down to the atomic level under dynamic conditions. Studies of the molecular changes in organic lubricants under dynamic loads employ infrared spectroscopy and interferometry.

Lubricating materials, bearings, seals and hydraulic fluids are being adapted to low-gravity, high-vacuum and extreme-temperature environments by a series of innovations. These include sputtering and ion plating processes to increase the service life of solid lubricants by more intimately bonding them to a substrate, new graphite-polyimide sealing materials to reduce leakage of shaft seals and compounding of hydraulic fluids and lubricants ("C"-ethers) which will operate over an extended service temperature range of $-20^{o}C$ to $320^{o}C$ ($0^{o}F$ to $600^{o}F$).

The degradation of the optical surfaces of high-power continuous-wave laser systems is being examined. The extent and mechanism of degradation after long periods of exposure to the laser beam or to chemical environmental effects is being cataloged. When this is done, procedures to formulate radiation-resistant materials will be devised.

New alloys with high fracture toughness over a wide range of temperatures (liquid hydrogen to 540°C or 1000°F) are being formulated. To help in this effort previous basic studies of the mechanisms by which refractory metals may be made less brittle are being applied to other systems including iron-base alloys. Technology of metal-matrix composites including graphite/aluminum for use in high temperature structures is being advanced. Basic studies of the wetability of graphite fibers by aluminum will be used to increase the strength of the fiber-matrix bond.

NEED AND RELEVANCY

This objective is in part an extension of tasks previously undertaken as part of the space shuttle technology program but modified so as to provide a sound technology base for the more advanced systems of the future. The space environment has imposed such special requirements upon materials as the ability to resist evaporation and decomposition in high vacuum, ability to function in zero-gravity, resistance to penetrating radiation and resistance to temperature extremes. To these are now added long life capability, moderate cost and even lower structural weight fraction. These requirements must be met whatever the space transportation systems of the future will be.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Direct Manpower (Head count)						
Manpower	48	43	43	43	43	43
Funding Requirement (K Dollars)						
Net R&D	690	500	525	525	525	550
IMS	636					
Total R&D	1326					
R&PM Resources	1656					
Total Value	2982					

b. RTOP Resources

		NEGOTIATED		BEST ESTIMATES			
		FY 74		FY 75		FY 76	
RTOP Number & Title	Center	Net $ (K)	Man-Power	Net $ (K)	Man-Power	Net $ (K)	Man-Power
502-31-50 Shuttle External Insul.	ARC	119	10.1	(Transfer to Thermal Prot. Syst. Obj.)			
502-21-20 Adv.Mats. for Space	LRC	100	7.0	75	8	75	8
502-31-50 Shuttle External Insul.	LRC	35	5.0	-	-	-	-
502-21-20 Adv. Mat for Space	LeRC	42	10.5	175	15	200	15
502-21-24 Mats. for Bearings Seals & Lub.	LeRC	95	4.0	250	20	250	20
502-21-33 Mats for High Power Lasers	LeRC	35	2.7	-	-	-	-
502-31-50 Shuttle External Insulation	LeRC	75	0	-	-	-	-
502-31-51 Bearings, Lub. & Seals for Shuttle	LeRC	89	9.0	(Combine with 502-21-24)			
TOTALS		690	48.2	500	43	525	43

c. Crosswalk Resource

1. 100% of resources of applicable relevance to "Space Systems Technology."

2. 60% of resources of applicable relevance to "Energy Conversion and Conservation."

3. 80% of resources of possible application to "Exploration of Space."

4. 25% of resources of primary relevance to "Shuttle Technology."

5. 50% of resources of possible application to "Civil Systems Technology."

2/20/74

TITLE: Control of Environmental Effects

TYPE OF SPECIFIC OBJECTIVE: _X_ DISCIPLINE _____ STUDY
_______ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Materials Program - Bernard G. Achhammer

Bernard G. Achhammer

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To improve materials and techniques which will provide long lifetime and greater reliability for spacecraft under space environmental conditions such as thermal excursions, space debris, micrometeoroids, and high energy radiation through accomplishment of the following:

Targets:

- o Demonstrate, by 1974, a 5,000 hour lifetime at 2400°F for a Lithium-Tantalum alloy heat pipe.

- o Generate, by 1975, a theoretical model of high energy (>100 MEV) particulate radiation (protons, neutrons, etc.) in the near earth environment.

- o Evaluate, by 1975, the nature and extent of near-earth man-made debris through ground based facilities and assess the need for flight data to generate predictor model.

- o Synthesize, by 1975, a white thermal control coating and demonstrate by laboratory testing a three-fold increase over the current one year space stable lifetime.

- o Demonstrate, by 1976, through accelerated laboratory tests, that second surface mirrors will have a minimum three year lifetime in inter-planetary or synchronous orbit and that their cost will be half that of optical solar reflectors (OSR at $3 a square inch).

This model provides the basic data for a near earth radiation model. This will be incorporated in a radiation transport program which constitutes the model of the high energy particulate radiation in the near earth environment.

- LRC will identify the population of debris large enough (>15cm) to be tracked by ground based radar. Since most space debris results from spacecraft explosions, simulated laboratory spacecraft explosions will be conducted to determine the velocity, the number and the size of particles smaller than 15cm which can be expected in such explosions. From this data the orbits of such debris can be established. The probability of spacecraft being impacted by such debris can then be calculated. If this probability is high enough to be of major concern, it will then be necessary to obtain actual flight data.

- MSFC will establish a monolithic particle size (½ to 1 u) zinc orthotitanate pigment by using the oxalate precipitation method, heat treatment, and surface passivation. OI 650 resin for the binder will be stabilized for long time use by end blocking and plastization. The CREF at IITRI will be used along with LRC's SEES facility and MSFC capability to determine space stability which should be $\Delta \alpha_s < 0.01$ in one year.

- LRC will investigate Kapton-Teflon and other polymer laminated materials as second surface mirrors. Silicones, urethanes, and acrylics will be assessed as potential adhesives for joining the second surface mirrors to the spacecraft surface. Simulated interplanetary radiation testing will be done at LRC's SEES facility and the simulated synchronous radiation environment testing will be done at a contractor facility to establish space stable lifetime.

- o Identify 1977, through ground and flight tests, sources which contaminate optical surfaces, the chemical reactivity of the contamination species with the surfaces, and assess the need for cleaning procedures.

- o Generate, by 1977, from Pioneer data a model of the meteoroid environment in the Asteroid Belt.

- o Demonstrate by 1978 predictable zero-g performance capabilities of heat pipes utilizing basic control mechanisms to provide temperature control of spacecraft equipment at temperatures as low as $20^{o}K$.

APPROACH

Thermal control of spacecraft will be emphasized with activities at ARC, LeRC, LRC, GSFC, and MSFC. Included is research and technology on heat pipes, thermal control coatings, second surface mirrors, and phase change materials. Contamination of thermal control and other optical surfaces will be investigated at LeRC and MSFC. LRC will concentrate on thermal control coatings, meteoroids, space debris and radiation shielding and dosimetry. Limited work on environmental design criteria to complete monographs in progress will be conducted at GSFC and JPL.

- o LeRC is investigating two approcaches to the oxygen corrosion problem in liquid metal-tantalum alloy heat pipes. These are an "in-situ" oxygen gettering technique using yttrium metal chips and a "preprocessing" technique to remove oxygen from the wick and the wall prior to operating the heat pipe in a normal fashion. Long time tests of such conditioned pipes in an operating mode will be conducted.

- o LRC is developing a heavy nucleus reaction model as a three step process which includes an initial impact where stripping processes occur, with an energetic "fireball" formed in the stripping region, followed by a decay of the high energy "fireball" and then the final decay of the stripped nuclei.

- o MSFC will test various materials that are commonly used in the vicinity of optical surface as possible contamination sources. These materials will be tested in so far as possible in the configuration of the intended use. The condensable constituents, or out-gases will be collected and identified as a function of temperature, exposure time, and radiation environment. The results of these tests will be compared directly with actual flight data from Skylab and other flight missions.

- o ARC will establish the zero-g performance capabilities of gas-controlled heat pipes with hydrodynamic capacities up to 50,000 watt-inch, thermal diode heat pipes at temperatures as low as $20^{o}K$, vapor-controlled heat pipes with moderate hydrodynamic capacities, and voltage-controlled heat pipes using electrodynamic wick systems. GSFC will emphasize a cryogenic nitrogen heat pipe. Flexible heat pipe development will be a part of this activity. Complete performance mapping of these pipes will be conducted in a 1g field. This will be followed by flight testing of the most promising candidates for the 0g environment.

- o LRC will use existing models of the interplanetary meteoroid environment and modify as required by Pioneer data to provide a model of the meteoroid environment in the Asteroid Belt.

Major milestones of the targets of this objective are:

Early FY 75 - Model of stripping and decay of "fireball" in high energy radiation studies will be completed.

Early FY 75 - The orbits and distributions of space debris larger than 15cm will be determined.

Early FY 75 - A zinc orthotitanate pigment (0.5 to 1 micron particle diameter) made by the oxalate precipitation method will be available.

Late FY 75 - Select the polymer laminate most suitable for second surface mirrors based on SEES facility testing.

Early FY 76 - Complete determination of the most common sources which contaminate optical surfaces.

Early FY 76 - Complete performance testing of cryogenic heat pipes in the 1g environment.

Early FY 75 - A preliminary model of the meteoroid environment in the Asteroid Belt will be generated based on Pioneer 10 data.

NEED AND RELEVANCY:

Spacecraft thermal control is critical to both man and environments as recently demonstrated by Skylab. To retain the effectiveness and reliability of thermal control surfaces as well as other optical surfaces in experimental packages, it is necessary to control contamination of these surfaces induced from many sources, such as thruster firings, materials outgassing, particulates and debris. The spacecraft must also be protected from meteoroid impact as well as impact with man-made space debris to prevent severe damage or even loss of a mission. The resistance of astronauts and equipment including various types of photographic film to high energy radiation must be determined to assess their capabilities and effectiveness in the space environment. These activities are in direct support of routine and economic space transportation and facilities with emphasis on lower cost and high performance effective systems.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	33	30	31	25	25	25
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	905	675	600	735	700	700
IMS	415	422	440	350	350	350
Total R&D	1,320	1,097	1,040	1,085	1,050	1,050
R&PM Resources	1,121	1,100	1,165	900	920	940
TOTAL VALUE	2,441	2,197	2,205	1,985	1,970	1,990

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man-Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man-Power	BEST ESTIMATES FY 76 Net $ (K)	BEST ESTIMATES FY 76 Man-Power
#502-21-27 Thermal Control (Heat Pipes)	ARC	250	4	250	4	150	4
#502-21-27 Thermal Control (Heat Pipes)	LeRC	50	6	50	6	70	6
#502-21-27 Thermal Control (Heat Pipes)	GSFC	50	1	50	1	100	2
#502-21-27 Thermal Control (Coatings)	MSFC	150	2	75	2	50	2
#502-21-27 Thermal Control (Second-Surface Mirrors)	LRC	110	3	100	3	80	3
#502-21-29 Space Debris	LRC	125	5	50	4	50	4
#502-21-28 Optical Contamination of Spacecraft	LeRC	-	2	-	2	-	2
#502-21-28 Optical Contamination of Spacecraft	MSFC	100	8	100	8	100	8
#502-21-32 Radiation Shielding & Dosimetry	LRC	60	1	-	-	-	-
#502-21-30 Environmental Design Criteria	GSFC	10	1	-	-	-	-
TOTALS		905	33	675	30	600	31

c. Crosswalk Resources

1. 20% of this objective is applicable tow cost technology for exploitation of space.

2. 20% is directed toward Shuttle exploitation technology.

3. 80% is directed to high performance effective systems.

2/20/74

TITLE: Thermal Protection Systems (TPS)

TYPE OF SPECIFIC OBJECTIVE: XX DISCIPLINE ___ STUDY______SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Materials Program - James J. Gangler

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide thermal protection system technology simulation test facilities and design concepts for probe missions to Venus, Saturn, Uranus, and Jupiter and for the Space Shuttle and advanced earth orbital vehicles. Specific targets are:

- o Evaluate heat shield material performance for a Venus probe by mid FY 1975
- o Identify failure modes and experimentally evaluate the thermal performance of Shuttle heat shield materials by FY 1976.
- o Experimentally verify in a simulated Venus entry environment the Venus probe heat shield design by mid FY 1976.
- o Evaluate TPS design for Saturn and Uranus entry probes by end of FY 1977.
- o By 1978 provide design verification of the Shuttle TPS using facilities that simulate the re-entry environment.
- o Provide TPS design data by FY 1979 on RSI and metallic systems for a reusable flyback launch vehicle compatible with the current shuttle orbiter.
- o By the end of FY 1980 establish the feasibility, preliminary design, and trade-offs for a Jupiter probe graphite heat shield and an alternate reflective heat shield that will allow reduction of heat shield weight by a factor of three.

Accomplishing this target depends on operational capability by FY 1979 of the ARC proposed Giant-Planet Entry Environment Simulation Facility.

- o Continue investigations on advanced TPS materials having improved stability and refractoriness.

APPROACH:

The aim of the Thermal Protection Systems program is to provide a technology base for heat shield designs that will permit entry into the atmospheres of the earth and the other planets in a safe, reliable, and predictable manner. An important feature of this program is the design and construction of unique test facilities that are capable of simulating the planetary atmospheres and entry conditions. These activities are carried out at the Ames and Langley Research Centers. The operating characteristics of the various arc-jets at these Centers are different from one another in terms of size, heating rates, type of heating, gas velocities, and pressures. Both Centers therefore are engaged in similar investigations but in different operating regimes.

Areas of emphasis are:

- o Shuttle TPS design and verification will be supported by Ames and Langley expertise and simulation facilities with emphasis on TPS panel evaluation including studies of gap heating, missing and defective tiles, bond line durability, tile orientation, and reusability.

- o Ames and Langley Research Centers will evaluate in arc plasma heating facilities the thermal and thermophysical performance, including reusability, of candidate shuttle heat shield and insulation materials and identify failure modes and material modifications that will improve the materials' performance.

- Improvements in RSI technology will be pursued by Ames by modification of fiber composition (silica fibers as well as other advanced fibers), control of impurity levels, use of new coatings, and optimization of processing parameters. A long range target of 1600°C, nearly 400°C above the current temperature capability, can realistically be expected as a result of these improvements.

- The Ames Research Center Arc-jets and Laser Facility will be used to study the potential of candidate heat shield materials and heat shield design for missions to Venus and the outer planets. Study of unique concepts that will permit lightweight heat shields and greater science payloads will receive particular attention.

Current facilities are not capable of fully simulating the severe probe heating which occurs during outer-planet entry. A concerted effort will be necessary to provide the required high-energy facilities. Planning has been completed and work is underway to provide a research model of a proposed Giant-Planet Entry Environment Simulation Facility which would permit testing with adequate model sizes and test time, and would provide levels of enthalpy, pressure, and heating similar to those of the Jupiter entry environment. To meet current mission planning schedules and technology readiness, the full-scale facility must be operational by FY 1979.

Major Milestones:

Early FY 1975	- Start verification testing of final Shuttle design.
Mid FY 1975	- Complete low-temperature RSI material characterization; 50% of reusable. carbon-carbon.
Mid FY 1976	- Identify heat shield candidates for outer planet probes.

NEED AND RELEVANCY:

The Agency is committed to developing a space shuttle system than can transport crew, passengers and cargo to low earth orbit at greatly reduced cost as compared to present systems. The design of the thermal protection system (TPS) is especially critical. Heat shield materials tests and TPS panel design and verification tests must be carried out in facilities that accurately simulate the proper entry environment.

Shuttle TPS investigations coupled with advanced heat shield materials studies also insures more efficient and versatile earth-to-orbit transportations systems at the appropriate times. Lightweight heat shields for planetary probes are essential if significant scientific payloads are to be flown to the planets.

Thermal Protection Systems are of primary relevance to the Agency's goals to <u>gain fundamental scientific knowledge</u>, <u>routine and economic space transporation</u> and to OAST emphasis on <u>technology for low-cost exploitation of space</u>.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	97	97	89	80	70	70
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1580	1350	1350	1350	1300	1300
IMS	1800	1650	1700	1700	1550	1550
TOTAL R&D	3380	3000	3050	3050	2850	2850
R&PM Resources	3250	3000	3000	3000	2600	2600
TOTAL VALUE	6630	6000	6050	6050	5450	5450

b. RTOP Resources

RTOP Number and Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man-Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
502-07-01 Planetary	ARC	84	4	50	4	50	4
502-27-01 Planetary	ARC	265	19	225	24	225	23
502-27-02 Earth Orbital	ARC	45	3	50	3	50	5
502-27-03 Earth Orbital	LRC	50	3	70	6	70	8
502-27-04 Planetary	LRC	105	4	–	–	–	–
502-31-50 Shuttle	ARC	119	10	100	10	100	10
502-37-02 Shuttle	ARC	398	37	400	37	400	31
502-37-02 Shuttle	LRC	515	17	455	13	455	8
TOTALS		1581	97	1350	97	1350	89

c. Crosswalk Resource

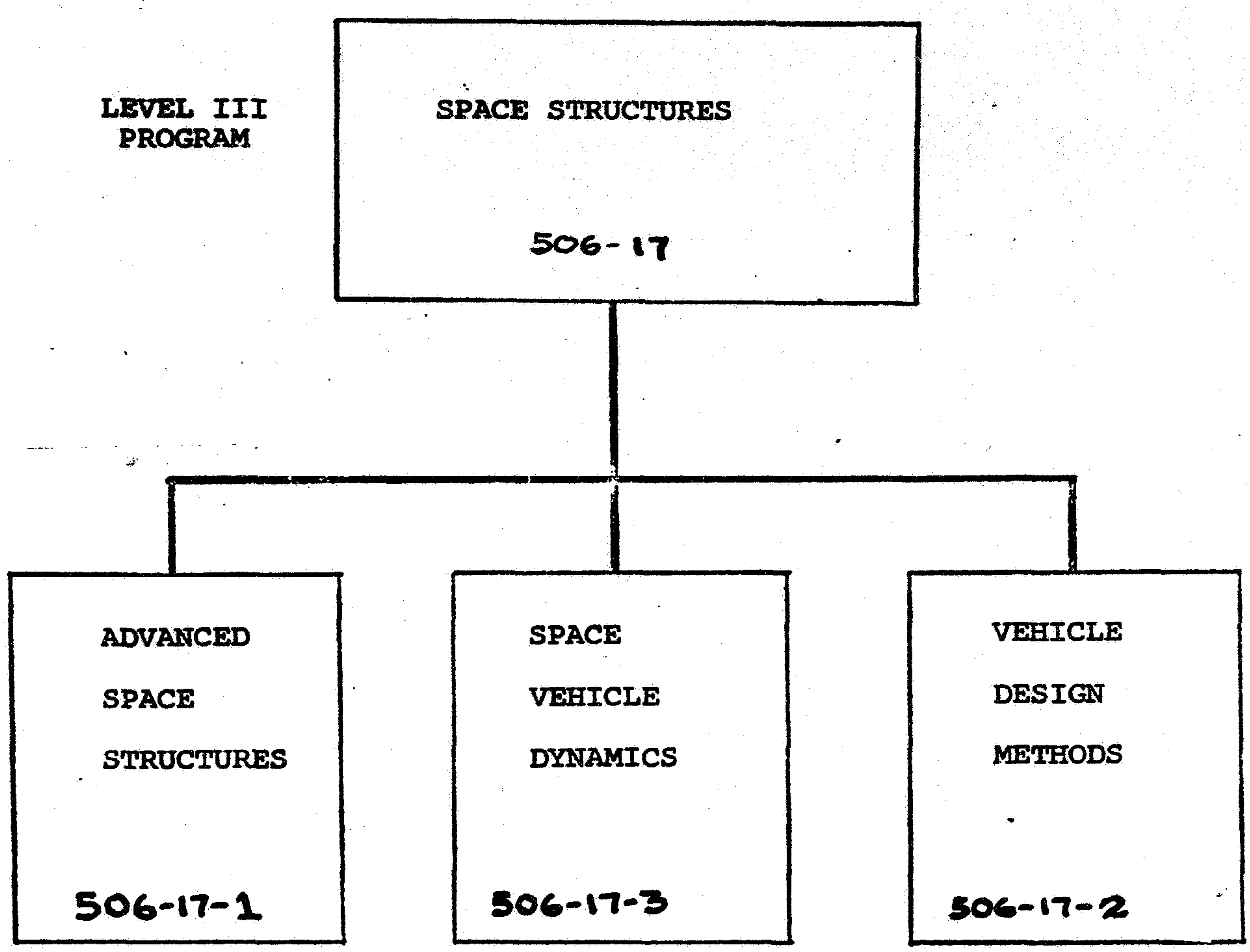
1. 20% of resources of primary relevance to the specific OAST focus of spacecraft and entry systems technology.

2. 100% of resources of primary relevance to the specific OAST focus on lower cost and high performance effective systems.

3. 70% of resources of primary relevance to the "specific OAST focus" of Shuttle technology.

4. 70% of resources of applicable relevance to the "specific OAST focus" of DOD support.

SPACE STRUCTURES WORK BREAKDOWN STRUCTURE



LEVEL IV SPECIFIC OBJECTIVES

SPACE STRUCTURES
RESEARCH AND TECHNOLOGY

Program Objective

Provide, through advances in the state-of-the-art, efficient cost effective structural concepts and advanced materials applications for future earth orbiting, planetary, and deep space spacecraft and launch vehicles. The objective includes:

- Advanced space structures, providing new concepts for erectable structures 10 times as large as currently available and the application of composites to reduce tank weight by 20% for Shuttle, Tug, and unmanned spacecraft.
- Space vehicle dynamics, analysis, and test methods which will reduce hardware certification cost by 10% for future spacecraft and payloads.
- Vehicle design data for Shuttle TPS and fracture control techniques for weight critical advanced spacecraft and payloads.

Research in support of the exploitation of space emphasizes methods to reduce the cost of spacecraft and payloads through improved techniques for response prediction and dynamic test requirements and to support the Shuttle development program with methods and data where OAST possesses special expertise and facilities. In support of the exploration of space, the program emphasizes the ability to meet stringent structural weight requirements and to provide unique erectable structures.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	105	110	115	120	120	120

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D	3167	3200	3600	3800	3900	4000
IMS	2048					
TOTAL R&D	5215					
R&PM Resources	3512					
TOTAL VALUE	8727					
EST. NET COSTS	3478					

TITLE: Advanced Space Structures

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE ____ STUDY ____ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Structures and Dynamics Program - Norman J. Mayer

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide technology which will lower cost and improve the operational effectiveness of future space systems through the creation of new concepts for expandable structures needed for microwave antennas, solar arrays, and reflectors, and by the exploitation of composites for major structural systems and subsystems. These objectives will be accomplished by achieving the following targets:

Targets:

- o Explore novel concepts for erectable large area space structures for application to large solar panels, radio telescopes, and other future applications.
- o Demonstrate by 1976, the feasibility of concepts for obtaining large diameter (15-100 ft.) furlable deep space antennas to operate at S, X and K band frequencies with high gain (up to 60 db) by means of RF and laboratory structural tests of a 5-meter flight-like moeel and extrapolation to larger size.
- o Demonstrate, by 1976, a weight saving of 20% using composite overwrapped metal tanks in place of present all-metal design for such application as Shuttle ECS tanks, through a laboratory fabrication and test program.
- o Demonstrate, by 1978, 30 percent weight savings by using thin-metal lined composite construction and 45 percent weight savings by using low-permeability polymeric lined all-composite construction, over metal tanks for application to future vehicles by means of a laboratory fabrication and test program.

APPROACH:

The activities under this objective will be conducted at the Langley and Lewis Research Centers and at JPL. The approaches leading to the accomplishment of each of the targets in the objective are:

Erectable Large Area Structures - A survey will be made to identify those missions which will require large area structures, and the operational and structural requirements for such missions will be defined. Approaches that will be investigated to meet these structural requirements will include the application of composites for lightly loaded structures tailored to provide highly concentrated stiffening arrangements; optimum use of hybrid composites; and use of intentionally reduced density composites.

Feasibility studies and benefit studies to evaluate weight, performance, and cost will be carried out. These studies will be accompanied by an in-house test program to evaluate fabrication and erection techniques as well as structural integrity and provide a data base to establish credibility of selected concepts.

Advanced Concepts for Spacecraft Antenna Structures - A five-step approach will be used in this program carried out in collaboration with RE for RF evaluation. The first step will be the identification of concepts (Structural and RF) for large deployable spacecraft antennas including methods of deployment. The conical antenna has been identified as the most promising new concept early in the program.

The second step will involve concept development, including design and construction of small-scale (6 ft. dia.) conical models for laboratory deployment and RF tests. This will include building and testing antenna components to evaluate basic feasibility.

The third step will be the design, fabrication and testing of new components with larger scale (14 ft. and 12 ft. dia.) conical antennas. Included in this step will be evaluation of line-source feeds at various frequency ranges to determine their suitability with conical reflectors.

The fourth step will be an evaluation and selection of materials for deployable conical surfaces and other structural components for the design of a 5-meter flight-like deployable conical antenna. The design will be followed by fabrication and testing of the antenna model for structural and RF performances.

The fifth step will be an extrapolation of the technology developed on the 5-meter flight-like deployable antenna to deployable antennas of larger sizes to show feasibility up to 30 meters. in diameter.

The entire program will provide a laboratory demonstration of the feasibility of achieving new and efficient antenna concepts for future spacecraft applications.

Composite Tank Technology - Primary efforts will include further development of new concepts for composite filament wound tanks directed toward establishment of the technology for near future application. This will be followed by fabrication of large scale test tanks with both thin metal and polymeric film, as well as cryoformed load-bearing liners. These specimens will be tested to demonstrate the target goals of weight saving and reliability.

The test program will be accompanied by the development of a fracture control plan and fracture data for overwrapped tanks.

The design and operational characteristics for a weight optimized, subscale, high pressure tank to meet future space vehicle requirements will also be developed.

Major milestones include:

Late FY 75 - Complete fabrication of 5M conical reflector by March 1975.

Late FY 75 - Complete tests of full-scale overwrapped tanks by March 1975.

Early FY 76 - Complete contract to perform parametric studies of various concepts for large area space structures by July 1975.

NEED AND RELEVANCY

Spacecraft of the future will perform functions involving energy transmission, energy generation, and energy control. These will include energy for spacecraft propulsion, control, and communication as well as terrestrial use. Preliminary mission studies have identified three specific areas of need:

A one megawatt solar array will require a surface area of 100,000 sq. ft. to support a sufficient quantity of solar cells. This could be obtained with a circular disc 357 ft. in diameter. Structural concepts must be developed which will provide feasibility for deployable structures of this size and larger.

Communication from deep space requires radio antennas which can operate at high frequencies. Data rate of 1×10^6 bits/sec. are required for meaningful resolution of outer planetary surface detail. Since power is limited, relatively small values (20-30 watts), this transmission rate can only be obtained by operating at S, X and K band requencies with large diameter (15-100 ft.) high gain antennas which must be deployed after launch. However, unless surface accuracy is tightly controlled (for example, .020 in. RMS at X-band) the efficiency of such large diameter antennas becomes too low to offer any gain in performance. Structural concepts must be developed and demonstrated to prove that these large size antennas with small dimensional tolerances can be obtained to meet future mission requirements anticipated for the 1980-85 period.

Present gas and liquid storage on board launch vehicles and spacecraft is limited to metal tanks which are near their optimum in terms of efficiency. Weight savings on space vehicles are worth between $1000-80,000 per lb. for shuttle type missions and values higher than this can be shown for upper stage long endurance orbital missions. Composite overwapped metal tanks offer weight savings of 20% over all metal tanks. All composite tanks with thin metal or polymeric liners would save an additional 10% to 25%. For a shuttle type vehicle a potential weight savings of over 400 lbs. can be obtained if only 1/3 of the tanks were composite construction.

The activities to be carried out under this objective will provide the technology needed to develop the large area deployable structures; the light-weight, deployable, yet structurally stiff antennas; and the light-weight reliable high pressure storage vessels needed to meet these needs.

RESOURCES:

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	12	18	23	25	25	25
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	935	900	1100	1200	1200	1300
IMS	95					
TOTAL R&D	1030					
R&PM Resources	251					
TOTAL VALUE	1281					

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	Man-Power	BEST ESTIMATES FY 75 Net $ (K)	Man-Power	FY 76 Net $ (K)	Man Power
#502-22-10 Advanced Space Structure	LaRC	170	2	300	7	500	11
#502-02-01 Large Laser Mirrors for Space	LeRC	50	1	50	1	200	2
#502-22-02 Composite Tank Technology	LeRC	150	2	150	2	100	1
#502-22-09 Composite Materials Application to Structures	LeRC	265	3	200	5	200	7
#502-22-05 Advanced Antennas	JPL	300	4	200	3	100	2
TOTALS		935	12	900	18	1100	2

c. Crosswalk Resource

100% - All work pertains directly to Advanced Space Systems.

2/20/74

TITLE: Space Vehicle Dynamics

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE ___STUDY ___SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY: Douglas Michel

Space Structures and Dynamics Program - Douglas Michel

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide dynamic and aeroelastic technology for the Shuttle development team to assist them in design of the vehicle, and to reduce the cost of future space systems through improvement of spacecraft acoustic and vibration analysis and test programs. These objectives will be accomplished by achieving the following targets:

- o Determine by 1975 the flutter characteristics of proposed Shuttle type TPS panels and the response of the panels in combined thermal-acoustic environments.
- o Determine by 1975 the vibration characteristics of a 1/8 scale model of the complete Shuttle and its components and compare with a NASTRAN analysis to support the Shuttle schedule for early evaluation of vehicle dynamic response.
- o Demonstrate a new flowmeter design by 1975 that will measure the perturbations in the flow velocity in a feedline to within 1% accuracy without disturbing the flow, for use in active systems for Shuttle POGO suppression.
- o Complete investigation of SRM main and drogue chute loads by FY 1975.
- o Demonstrate by FY 1976 pre-flight flutter clearance of the Shuttle throughout its operating flight envelope.
- o Determine pre-launch ground wind loads on the Shuttle and launch complex by FY 1977.
- o Determine loads in areas of turbulent flows and loads due to exhaust plume by late FY 1975.
- o Define spacecraft/payload vibration and acoustic analysis/test procedures by 1978 which will reduce hardware certification cost by reducing the analysis/test requirements and cost by 10%.

APPROACH:

The Space Vehicle Dynamics program includes the shuttle dynamics and aeroelasticity program and the spacecraft dynamic analysis/test qualification program.

The purpose of the OAST program in shuttle dynamics and aeroelasticity initiated in FY 1969 is to identify potential problem areas requiring further research and to provide the shuttle development team with design data in a timely fashion. Much of the program has been completed and the current effort is directed primarily toward providing design data in a few isolated areas.

Preliminary flutter studies of simple RSI tiles on elastic foundations (strain isolator) indicate ample flutter margins for shuttle panels within the Shuttle trajectory. However, the inclusion of multiple tiles and uniform shear in the primary panel may have significant influence on flutter speed. Under a Langley grant, a flutter analysis is being developed to assess specific shuttle TPS designs by FY 1975. Wind tunnel verification will be required if analyses indicate marginal designs.

Dynamic response and fatigue data are also needed to design the TPS panels. For this purpose Langley will test shuttle type TPS panels using RSI tiles on skin-stringer aluminum substructure. Tests will be done in the High Intensity Noise Facility at Langley (HINF) under combined thermal and acoustic environments to simulate the shuttle mission cycles. Analytical procedures will also be developed for predicting the response of the panels. An upgrading of the HINF, started in FY 1974, will improve noise input spectrum shaping and increase the temperature range from 1200°F to 1700°F. Panel preload and cold soak will also be made available.

In order to obtain an early evaluation of experimental and analytical methods for obtaining the dynamic characteristics of the overall shuttle vehicle, a 1/8 scale model of the shuttle will be tested in the Structural Dynamics Research Laboratory at Langley. While the model is not identical to the shuttle in detail, it should uncover major problem areas peculiar to a shuttle-type configuration. The model has been completed and tests of the orbiter alone began in early FY 1974. Tests of the complete model began in mid-FY 1974. Various fuel conditions related to mission time will be investigated. Water will be used to simulate oxygen, styrofoam pellets will be used to simulate hydrogen, and a viscoelastic inert solid propellant will be used in place of the active propellant. A mathematical model has been developed for use in the NASTRAN analysis to guide the tests and to provide agreement with the test data. The combined analysis/test program will be completed by mid-FY 1975.

POGO is a potential problem for any liquid rocket but is of concern for the Shuttle because the structural and fuel system natural frequencies are expected to be much closer together than in previous launch vehicles and the probability for unstable coupling is therefore greater. Knowledge of the propulsion system dynamic characteristics is essential to the determination of stability margins and consequently, whether a POGO suppression system is needed. Both passive and active suppression systems are being considered. If an active system is used, it must be activated by a sensor that will detect the velocity fluctuations in the fuel flow without interfering with the flow itself. The instrument must also be capable of detecting an oscillating flow velocity that is only about 1/100th the magnitude of the steady flow, since experience shows the POGO thrust oscillations are only about 1/100th of the total thrust. A nonintrusive ultrasonic flowmeter, which will detect frequencies from 0 to 100 Hz will be evaluated by Langley in a 3" line using water, and by the National Bureau of Standards in a 3" line using liquid nitrogen. It may also be tested at Marshall in a 12" line using LOX.

To assure that the Shuttle is free from flutter throughout its operating envelope, particularly at high dynamic pressures in the transonic range, a series of analytical and wind tunnel investigations are being conducted. Preliminary flutter studies on component models have been completed in the Langley 26-inch transonic blowdown tunnel to evaluate wing/body interference effects on flutter and to determine wing/elevon and fin/rudder flutter boundaries. Follow-on studies will be conducted in the Langley Transonic Dynamics Tunnel on cantilevered component models in early FY 1975 and on complete models in late FY 1976. In addition a dynamically scaled complete model on a cable mount system will be utilized to investigate other vehicle dynamic characteristics such as gust response and dynamic stability and control at transonic speeds. Flight flutter testing and data analysis techniques are being developed with the aim of being able to predict, by FY 1976, flutter margins of safety from structural response measurements obtained at speeds below flutter.

In FY 1977 ground wind load effects will be determined for the Shuttle and its launch complex utilizing dynamic aeroelastically scaled models in the Langley transonic dynamics tunnel.

Fluctuating pressure loadings (aerodynamic noise) in areas of high turbulent flow are important in the design of the structure. Examples of such areas are where the shock from the orbiter impinges on the fuel tank and vice versa. The impingement of the exhaust plume on the vehicle also causes high loadings. Ames will complete development of a cold-jet exhaust plume simulator for the Ames Unitary Wind Tunnel Facilities by late FY 1974 and investigate plume steady state and dynamic effects. Aerodynamic noise tests on a 4% Shuttle model will be completed by late FY 1975.

The costs of current dynamic test/analysis programs for certifying spacecraft hardware are excessive. A program was started in FY 1974 to examine all aspects of the problem and to determine the approaches to solving it. Goddard will be performing cost studies involving the optimum test level and the cost effectiveness of subsystem testing. JPL will evaluate current design criteria, loads designs, development and qualification tests, and flight data on past, current and future NASA programs. They will also examine permissable weight, schedule, risk, cost and organizational interfaces of each program to provide a data base to establish cost reduction tasks in the more fruitful areas. Their current costs of the Viking Orbiter design approach and test/analysis program will be compared. Marshall will be investigating the feasibility of nondestructive qualification tests of flight hardware, developing impedance techniques to predict the response of spacecraft to loads, defining the advantages and limitations of free-field and reverberation acoustic tests, and developing a method for orienting payloads in the Shuttle so the loads act in a preferred direction. Ames will report the results of their investigations on intensity, spatial correlation, and scaling of pressure fluctuations measured in supersonic separated-flow and shock-wave regions -- one of the major sources of loadings on spacecraft. Langley will investigate measurement methods for determining the payload environment, develop closed-loop dynamic test methods, and optimize active vibration isolation schemes. This low cost analysis/test program will be evaluated, revised, and updated prior to FY 1975 to concentrate the effort in those areas promising the higher payoffs.

Also under this objective is the development of a structural-thermal-optical program (STOP) by Goddard that is compatible with NASTRAN, and into which it will be installed at Goddard in early FY 1975. This objective also provides NASA's share of support to the Shock and Vibration Information Center (SVIC).

NEED AND RELEVANCY:

The work under this objective in the area of shuttle dynamics and aeroelasticity is directed toward providing the shuttle contractor with analytical methods, test techniques, and design data that can be used in the shuttle program. In some cases the work is actually being done by or will be done with the shuttle contractor, but in all cases the results of the investigations will be made immediately available to him. For example, the Langley tests of the 1/8 scale dynamic model of the shuttle will provide early response data which can be obtained in no other fashion so that design changes can be made, if required, at an earlier stage of development.

For many years we have been testing spacecraft and their components to load levels that were higher than any load experienced in flight. This conservatism, which comes through our uncertainties in predicting dynamic loads and responses drives up the vehicle design test requirements. The result is that we spend more for test programs than we should, we pay for unnecessary redesign of vehicles that failed laboratory tests but which may have been adequate in flight, and we sometimes end up with a more expensive complex design in trying to save weight and still meet the load requirements. There is obviously a dire need to provide the necessary technology to arrive at more rational dynamic analysis/test programs that will result in reduced cost for our spacecraft. A cost survey of past vehicle developments shows that up to 25% of the total vehicle costs are attributable to dynamic tests and analysis. Through more material logic it is estimated that up to 10% of the test analysis costs can be saved.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	41	50	50	53	53	53
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	956	1100	1100	1300	1300	1300
IMS	892					
TOTAL R&D	1848					
R&PM Resources	1366					
TOTAL VALUE	3214					

b. RTOP Resources

		NEGOTIATED		BEST ESTIMATES			
		FY 74		FY 75		FY 76	
RTOP Number & Title	Center	Net $ (K)	Man-Power	Net $ (K)	Man-Power	Net $ (K)	Man-Power
502-22-11, Space Vehicle Dynamics	ARC	200	7	175	7	175	7
502-32-02, Space Shuttle Dynamics & Aeroelasticity	ARC	80	2	100	2	100	2
502-22-11, Space Vehicle Dynamics	LRC	250	10	250	10	280	9
502-32-02, Space Shuttle Dynamics & Aeroelasticity	LRC	181	17	275	23	250	23
502-22-11, Space Vehicle Dynamics	MSFC	90	1	100	1	100	1
502-22-11, Space Vehicle Dynamics	GSFC	50	3	55	2	75	2
502-22-06, STOP	GSFC	-	0.5	30	1	0	1
502-22-11, Space Vehicle Dynamics	JPL	60	1	70	4	75	5
502-22-07, SVIC	HQ	45	0	45	0	45	0
TOTALS		956	41	1100	50	1100	50

c. Crosswalk resources

1. 40% of resources of primary relevance to "shuttle technology."
2. 60% of resources of primary relevance to "low cost and high performance effective systems."
3. 60% of resources of applicable relevance to "spacecraft and entry systems technology."
4. 60% of resources of applicable relevance to "civil systems technology."
5. 60% of resources of possible application to "DOD support."

2/20/74

TITLE: Vehicle Design Methods

TYPE OF SPECIFIC OBJECTIVE: __X__ DISCIPLINE ____ STUDY ____ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Douglas A. Gilstad

Space Structures and Dynamics Program - Douglas A. Gilstad

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide advanced design techniques including automated analysis and design methods, fracture control and life prediction methods, and test data which will greatly improve capabilities for development of efficient, reliable, and cost-effective space vehicles.

Targets:

- Satisfy Shuttle project requirements by upgrading NASTRAN capability and increasing efficiency by an order of magnitude by FY 75.
- Formally release NASTRAN Level 16.0 to the U.S. aerospace industry in FY 75.
- Install subsonic flutter capability in NASTRAN in FY 75.
- Determine by FY 76 the impact of fourth generation computers on the NASTRAN program and the costs involved in converting it to fourth generation equipment.
- Complete evaluation of Candidate Shuttle TPS structures in FY 76 in high-temperature wind-tunnel tests.
- Evolve by FY 79 the fracture control methodology, supporting test data, and NDE techniques needed to provide reliable long life, lightweight structures and components for weight-critical systems having a 100-mission re-use capability and a 10-year life.
- Provide TPS design options by FY 80 for future high-speed vehicles such as fly-back boosters and advanced spacecraft.

- Provide design subroutines for IPAD by FY 80 that will provide for those requirements unique to space vehicles, such as launch and entry conditions, and will reduce design cycle time by more than 50% with a corresponding reduction in design cost.

APPROACH:

The development of technology advances needed for space vehicle design methods is conducted primarily at Langley and Lewis Research Centers. Emphasis is given to shuttle structures support and fracture control technologies. Previous shuttle technology activities have provided NASTRAN capability and other advanced structural analysis programs, laboratory demonstration of potential composite structures applications, design criteria, and investigation of numerous structural design options for the shuttle. The major shuttle support effort being continued in this objective will provide evaluation of TPS structures in high temperature structural test facilities. Past efforts on fracture control have emphasized the critical factors associated with flaw behavior and the design and test procedures necessary to insure achievement of the required strength and reliability of pressure vessels. These activities are being expanded to include fracture control technology for light-weight space tug engines, development of advanced NDE techniques, and criteria for thin-walled tanks.

New automated analysis and design methods will be developed in the Aeronautics Structures program. Many of these will find application to space vehicle structures with suitable additions and modifications to reflect unique space vehicle conditions.

- Additional improvements to NASTRAN to meet Shuttle needs include automated modal synthesis to handle the dynamic interactions among orbiter, external tank, and solid rocket motors; and three-dimensional hydroelastic capability to handle fuel-structure interaction problems in the external tank. The shell analysis computer programs SRA and STAGS will be applied as needed to investigate special shuttle vehicle structural problems where the accuracy of shell theory is required to resolve an important issue or where nonlinear structural behavior is involved.

- Level 16.0 of the NASTRAN program will be completed in mid-FY 74. A prerelease will be made to the U.S. aerospace industry in order to check it out. It is anticipated that during FY 75 the NASTRAN maintenance effort will be devoted mainly to error correction with very little, if any, addition of new capability. A possible exception is the installation of subsonic flutter capability, the development of which is almost complete.

- Third generation computers have been used in the aerospace industry for about six years and they will see continued use even after the fourth generation computers are introduced in about 1976. NASTRAN can run on three of the third generation computers and, with modification, it is expected to run on a fourth generation computer such as STAR. However, it may be more efficient to rewrite the NASTRAN program than to modify it. A contract will therefore be let in FY 75 to study the impact of fourth generation equipment on NASTRAN and the costs involved in converting it.

- The High Temperature Structures Tunnels at LRC are unique facilities for imposing realistic temperature and loading on thermal protection systems with hypersonic flow conditions. Preliminary tests of various Shuttle TPS are underway in the 8-Ft. HTST and tests in the Thermal Protection System Test Facility (TPSTF) will begin early in FY 75 following completion of construction and calibration of the facility. Both the 8-Ft. HTST and the TSTF are combustion-driven facilities. Hence, an effort is required to assure correlation with air tunnels. Heating and pressure data obtained in the 8-Ft. HTST at H_T = 1000 BTU/lb have been shown to correlate with similar data in arc-heated air and with theory. Application of these correlation methods will be made to data obtained in the TPSTF at H_T = 4400 BTU/lb. Data will be obtained when the TPSTF becomes operational and the correlations should be completed by 1975. The testing to be conducted in FY 75 and 76 will be in support of the overall Shuttle project TPS development plan currently being defined. TPS title arrays up to 3-1/2 x 5 ft. and control surface components will be tested in the 8-Ft. HTST with test durations up to 200 seconds representing a portion of the critical shuttle entry heating pulse. In the TPSTF, TPS tile arrays 2 x 3 ft. will be tested with test durations up to 2000 seconds representing the entire heating pulse of significance. Frequency of testing in these facilities will be impeded until completion of modifications in FY 75 to the 6000 psi. bottle field which provides the air supply for tunnel operation. The tests required for evaluation of the Shuttle TPS structures should be completed by the end of FY 76. After completion of Shuttle TPS development, the 8-Ft. HTST and TPSTF will be key facilities for generations of aerothermal performance and service life data for numerous types of TPS to provide design options for future high-speed vehicles.

o The fracture control technology activities are conducted at LeRC and are primarily contracted efforts. Because future reusable space transportation systems like the Tug will be extremely weight critical, fracture control methods must be extended to make possible the design of lightweight components while increasing the reliability and service life. To define a fracture control plan for an H-O Tug engine, prospective design requirements will be established in FY 75, potential failure modes will be identified in FY 76, and the needed fracture control data will be developed by 1978. Other studies will establish design and proof test procedures for thin-walled pressure vessels to meet service requirements for cyclic loading, develop advanced proof test methods to enhance flaw detection capabilities, and evaluate improved NDE techniques that can be used in the field and in-flight to monitor the integrity of critical components. The foregoing studies will provide the necessary fracture control methods for the Space Tug by 1978. In addition, efforts will be continued on the effects of combined loading on flaw growth and analytical methods for prediction of crack growth. A related effort at LeRC is directed toward increasing the reliability of nondestructively detecting the critical-size flaws in structural components. Particular emphasis is on flaw-detection near weld zones. This nondestructive evaluation (NDE) effort is initially directed toward defining the sensitivity and reliability of currently-used inspection techniques for the materials and configurations of interest. This should be completed in 1975. Improved NDE processes will be subsequently developed for areas where the inspection capabilities are inadequate to meet the fracture control criteria. These improvements will be approached through the application of more advanced inspection techniques and through use of more automated analysis and interpretation of NDE test data.

- Efforts to develop design subroutines for IPAD which will incorporate methods for unique space vehicle requirements will be initiated when the IPAD system has been clearly defined in the Aeronautics Structures program. It is expected that the work on the space vehicle computer modules will begin in FY 77 leading to release of design subroutines by 1980.

NEED AND RELEVANCY

Finite element analysis has provided a versatile capability for handling a great many structural problems on the computer. The NASTRAN program is the foremost example of a finite element analysis program. For example, since the release of NASTRAN by NASA in 1970, it has been used on almost every NASA spacecraft and launch vehicle. It is currently being used by over 2,000 engineers in the U.S. in 59 installations in the aerospace industry (includes NASA Centers, DOD, aerospace companies) and over 180 companies outside the aerospace industry, and the number of users is increasing at a rate of about 50% per year. The basic features of NASTRAN such as matrix algebra techniques, building and decomposition of the stiffness matrix, and the finite element library require continuous improvement to keep it competitive with state-of-the-art techniques and compatible with constantly evolving hardware. New capability also needs to be added as guided by the experience and needs of the many NASTRAN users. One example is the request of some aircraft companies for the addition of aeroelastic capability.

The testing of Shuttle TPS components is of primary relevance to Shuttle technology. The development of an efficient and reliable TPS is most critical to the success of the Shuttle, and the tests in this objective are key elements in the overall evaluation of the TPS. Other related tests will be conducted at other NASA Centers, AEDC, and contractor facilities as portions of the program to develop an acceptable TPS for the Shuttle. All of these tests will be necessary to demonstrate, insofar as practicable in ground-based facilities, that the shuttle TPS will adequately withstand the conditions to be encountered in its required 100 mission lifetime.

The Shuttle structural design will be finalized within the next year. The importance of the Shuttle program to the nation and the agency demands that the most advanced structural analysis tools such as NASTRAN, STAGS, and SRA be available and ready to help insure the adequacy of the structural design.

The advancement of fracture control technology has primary relevance for Space Systems technology. Minimum weight and maximum reliability are critical requirements for advanced reusable space transportation systems such as the Tug, and the thrust of this activity addresses these needs. Previous Tug system studies have indicated cost/weight sensitivities of $150,000 per pound in development and operational costs over the life of the system with a life of 20 missions per vehicle. Current planning for an advanced reusable Tug anticipates no fixed limit on life or number of mission. Components or subsystems would be replaced as necessary to maintain the system in operational status. This approach will require high reliability in the engine and structural subsystems with a comprehensive fractures control plan and NDE procedures to insure that potential deficiencies are expeditiously identified.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER						
Manpower	52	42	42	42	42	42
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1276	1000	1400	1400	1400	1400
IMS	1061					
TOTAL R&D	2337					
R&PM Resources	1895					
TOTAL VALUE	4232					

b. RTOP Resources

		NEGOTIATED		BEST ESTIMATES			
		FY 74		FY 75		FY 76	
FY 74 RTOP Number & Title	Center	Net $ (K)	Man-Power	Net $ (K)	Man-Power	Net $ (K)	Man-Power
#502-22-08 General Purpose Anal. & Design Tech.	LRC	501	7	350	7	600	14
#502-32-01 Shuttle Struct. Design Tech.	LRC	370	42	350	30	300	20
#502-22-03 Fracture Control Tech.	LeRC	350	2	225	3	300	5
#502-22-12 Nondestructive Evaluation of Space Struct.	LeRC	55	1	75	2	200	3
TOTALS		1276	52	1000	42	1400	42

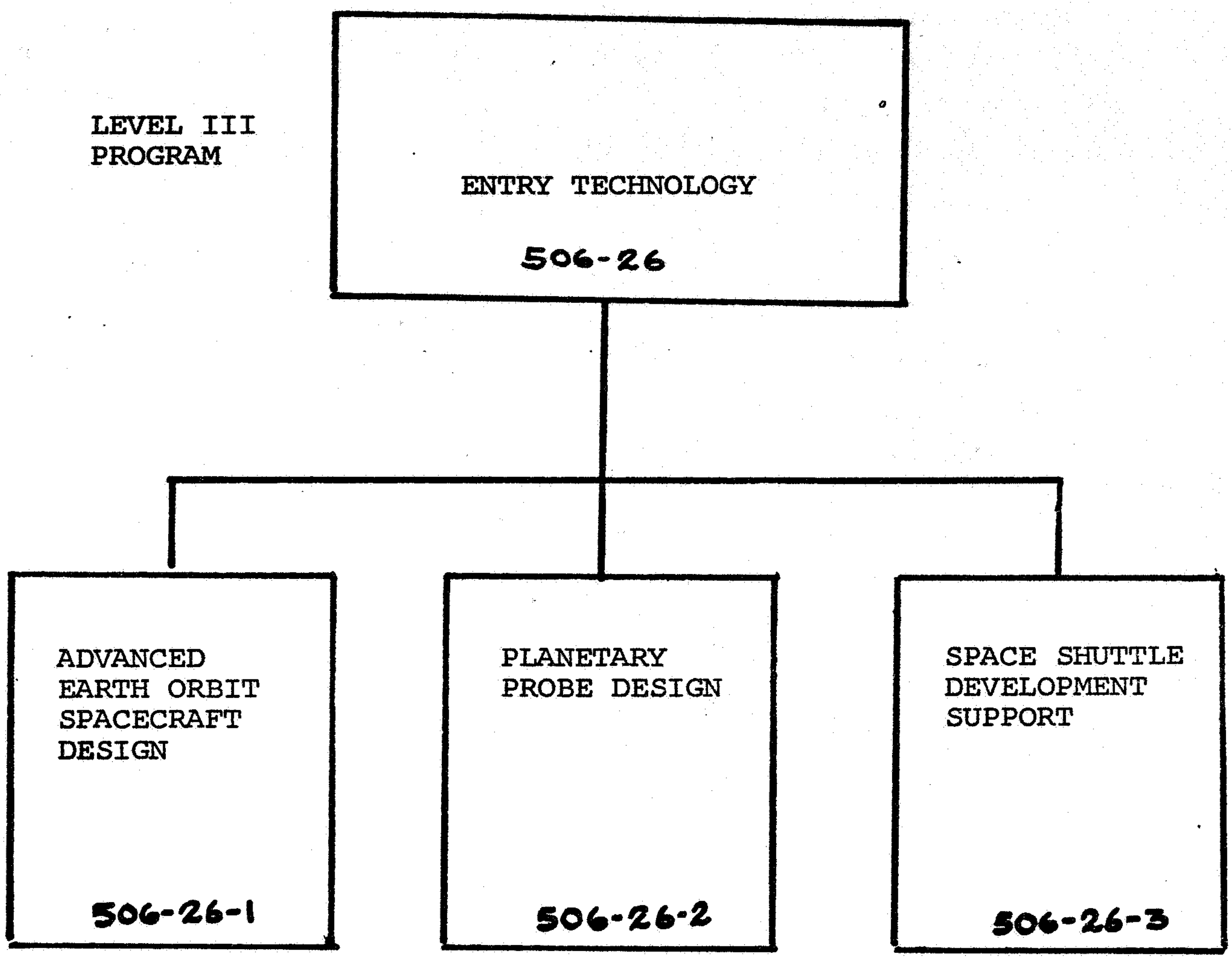
c. Crosswalk Resource

1. 35% of resources of primary relevance to the "specific OAST focus" of Shuttle Technology

2. 65% of resources of primary relevance to the "specific OAST focus" of Space Systems Technology

ENTRY TECHNOLOGY WORK BREAKDOWN STRUCTURE LEVEL

III & IV



LEVEL IV SPECIFIC OBJECTIVES

TITLE: Entry Technology

Program Objective

Provide the aerothermodynamic technology base that will be required to improve entry spacecraft design, safety, and reliability and assure more efficient aerodynamic operation for earth orbital missions and planetary exploration. The program will provide:

- o Ground test support and technical analysis expertise for shuttle aerodynamics and heating loads during design, development and verification phases.
- o Planetary entry aerothermodynamic technology for the design of probes maximizing science payload capability for missions to Venus, Saturn, Uranus and Jupiter.
- o Design technology for advanced reusable low-cost earth orbital spacecraft with greater aerodynamic efficiency.

NASA's work in entry technology played a critical role in this country's missile design and formed the foundation for the Mercury, Gemini and Apollo space missions.

Current and future technology is aimed at more efficient and reliable spacecraft design concepts that can deliver greater payloads at lower cost into planetary atmospheres and to design concepts for more efficient earth orbital transportation systems. Emphasis is on low earth orbit and exploratory planetary probe missions.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Direct Manpower (Head Count)						
Manpower	270	249	223	214	212	217

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D	1533	1700	2580	2490	2470	2470
IMS	3923	4178	3050	2887	2908	2978
TOTAL R&D	5456	5878	5630	5377	5378	5448
R&PM Resource	9335	8530	7577	7190	7231	7366
TOTAL VALUE	14791	14408	13207	12567	12609	12814
EST. NET COSTS	1756	1800				

TITLE: Advanced Earth Orbital Spacecraft Design

TYPE OF SPECIFIC OBJECTIVE: XX DISCIPLINE
_____ STUDY _____ EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Entry Technology - J. E. Greene; P. A. Cerreta

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To establish the aerothermodynamic technology base to the levels required to support future agency and national goals in areas of efficient, two stage fully reusable systems, single stage to orbit systems, orbit to orbit systems, and cost effective space transportation encompassing semi-global range capability. Specific targets are:

- o In FY 1975 investigate feasibility of aerodynamic maneuvering orbit to orbit spacecraft.
- o By mid FY 1975 develop methodology for evaluating advantages and sensitivity of spacecraft concepts to various technology advances.
- o Continue investigation of advanced spacecraft concepts with potential for cost and weight reduction and improvement in performance, stability and control systems.
- o Identify by FY 1976 those missions characteristics and associated vehicle systems which offer maximum potential for efficient and economical space transportation.
- o By FY 1976 establish focused technology paths required to achieve space transportation needs of the nation in the post 1990 time frame.
- o By FY 1978 complete computer codes for ILLIAC and STAR that numerically simulate the complete three-dimensional flow field including viscous effects about spacecraft.
- o By FY 1978 establish key technology programs to provide a firm base for development of the maximum capability system.

APPROACH:

Research is carried out by Ames and Langley Research Centers to identify requirements and acquire aerothermodynamic technology for the design and operation of advanced earth-orbital vehicles in the late 1980's and beyond. The intent is to derive concepts which offer significant advantages in the areas of reusability, performance, heat transfer, and flying qualities by building upon the technology base developed under the Space Shuttle Program, and from the projected advances within this decade in materials, structures, propulsion efficiencies, electronics, etc. Candidate concepts will be evaluated through a series of trade-off analyses and parallel experimental investigations of real gas effects, heat transer in low Reynolds number high Mach number viscous interaction regions, flow fields for verification of advanced calculation methods as well as basic body shaping and realistic configuration optimization.

- o Langley will provide a lead center role to identify vehicle concepts and technology which can lead to reduced cost and weight, improved performance and stability and control, and better handling qualities and control systems.

- o At the Ames Research Center, analytical and/or semi-empirical techniques will be developed to aid in predicting the lee-side heating rates for typical entry vehicles. First phase aerothermodynamic investigation will be a parametric, experimental study of lee-side flows which will be used to generate or verify prediction techniques.

NEED AND RELEVANCY:

Based on NASA experience with past and current manned flight programs, at least 15 years lead time may be required as a minimum to develop the technology for advanced earth-orbital spacecraft. The technology base establihsed for the Space Shuttle Program coupled with further technology advances in such areas as structures, materials, propulsion, and aerothermodynamics, will help to ensure that the nation is prepared to proceed with the development of more efficient and versatile earth-to-orbit transportation systems at the appropriate time.

Advanced earth-orbital spacecraft design is of primary relevance to NASA's goal of routine and economic space transportation and facilities. It has direct application to the OAST emphasis on technology for low-cost exploitation of space and advanced technology for superior future aircraft and focus on lower cost performance effective systems and hypersonic aircraft technology.

OAST emphasis on technology for low-cost exploitation of space and focus on lower cost performance effective systems.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	34	48	66	80	90	95
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	285	285	585	730	795	825
IMS	495	846	960	1160	1310	1380
TOTAL R&D	780	1131	1545	1890	2105	2205
R&PM Resource	1235	1743	2400	2905	3270	3420
TOTAL VALUE	2015	2874	3945	4795	5375	5625

b. RTOP Resources

	RTOP No. & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man-Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man-Power	BEST ESTIMATES FY 76 Net $ (K)	BEST ESTIMATES FY 76 Man-Power
(502-27-02)	506-26-10	ARC	45	2	35	3	90	4
(502-27-02)	506-26-10	LRC	240	32	250	45	495	62
	TOTALS		285	34	285	48	585	66

c. Crosswalk Resource

1. 100% of resources of primary relevance to the specific OAST focus on lower cost and high performance effective systems.

2. 30% of resources of primary relevance to the specific OAST focus on hypersonic cruise aircraft design technology.

TITLE: Planetary Probe Design

TYPE OF SPECIFIC OBJECTIVE: XX DISCIPLINE
_____ STUDY ____ EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Entry Technology - J. E. Greene; P. A. Cerreta

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide the technology base in high-speed aerothermodynamics required for entry into the atmospheres of Venus, Uranus, Saturn and Jupiter, and to support, in a timely manner, the specific development of planned and approved missions. Major targets are:

- o Continue experimental and theoretical investigation of high energy flow processes associated with very high-speed planetary entry. Research emphasis will be on thermodynamic and transport properties of gases, kinetic rate processes, radiation transfer, and computer codes and technique for numerical simulation of real gas flows.
- o Employ previously developed analytical techniques and experimental facilities to determine by mid-FY 1975 the influence of probe configuration, trajectory, and ablation material on heating and aerodynamic performance during entry into Venus atmosphere.
- o Develop and employ, by the end of FY 1977 for Uranus and Saturn, the analytical and experimental methods required to predict the aerothermodynamic entry environment and to perform probe systems design and trade studies.
- o Develop and employ, by the end of FY 1981, the analytical and experimental methods required to predict the aerothermodynamic entry environment and to perform probe systems design and trade studies for a Jupiter entry probe.

APPROACH:

The planetary probe design technology program is keyed to the NASA mission model for exploration of the solar system. This program will provide a technology base for design that will permit entry into the atmospheres of the planets in a safe, reliable, and predictable manner with a maximum science payload. To fulfill this objective, Research Center responsibilities are as follows:

- o Ames Research Center has primary responsibility for the highly focused research activities which are necessary to a basic understanding of high-energy fluid flows.
- o The Langley Research Center is responsible for developing a major portion of the analytical techniques and ground facility techniques required to predict the thermal and aerodynamic environment of probe vehicles over a broad range of planetary missions and to predict vehicle response in the entry environment.
- o The Jet Propulsion Laboratory is responsible for determination of gas dynamic behavior about probes in very high speed outer planet atmospheric gases.

The required levels of effort will increase moderately through the rest of this decade in order to meet technology readiness dates ranging from 1975 for Venus to the early 1980s for Jupiter probe missions.

Areas of emphasis are as follows:

- o Shock tube and other unique facilities at the Ames and Langley Research Centers and the Jet Propulsion Laboratory will be used to investigate rate and radiation processes occurring in gas mixtures representative of planetary atmospheres at shock velocities commensurate with entry speeds of Venus and the outer planets.
- o The critical problem of ablation product blockage of radiative heating will be studied in the LaRC Planetary Entry Radiation Facility (PERF), the soon to be operational reconfigured PERF, and a future downstream version of the PERF.
- o Hypervelocity convective heating and aerodynamic performance of candidate probe configuration will be investigated in the LaRC 6-inch Expansion Tube and Hypervelocity CF_4 Tunnel.
- o Complete, reliable, and convenient computational methods, for use on STAR and conventional computers, will be developed for predicting the interaction of planetary entry probes with their environment and for optimizing probe design from the point of view of potential science return and low cost.

- o Definition and preliminary design of an earth-entry flight experiment, with a target launch date of mid-1978, will be undertaken to provide a validation of entry probe performance prediction methodology and otherwise unobtainable empirical data on boundary layer transition, turbulent heating, and base heating under conditions of rapid ablation and severe radiative heating.

- o Evaluate and document experimental data on the effects of mass addition on boundary layer transition on blunt atmospheric entry configurations.

Current facilities are not capable of fully simulating the severe probe heating which occurs during outer-planet entry. A concerted effort will be necessary to provide the required high-energy facilities. Planning has been completed and work is underway to provide a research model of a proposed Giant-Planet Entry Environment Simulation Facility which would permit testing with adequate model sizes and test time, and would provide levels of enthalpy, pressure, and heating similar to those of the Jupiter entry environment. To meet current mission planning schedules and technology readiness, the full-scale facility must be operational by FY 1979.

Basic research performed at the centers is aimed at acquiring an understanding of the characteristics of high energy fluid flows and related aerothermodynamic phenomena. This research is necessary in order to identify and understand problems relevant to planetary missions and is primarily concerned with areas such as thermodynamic and transport properties of gases, kinetic rate processes, radiation transfer, and development of computer codes and techniques for numerical simulation of real gas flows.

Major milestones in Planetary Probe Design are:

Mid-FY 1975

- o Complete Pioneer Venus heating prediction methodology development.

- o Complete benchmark computer codes for Uranus and Saturn entry heating.

- o Computer code development, combined viscous/ inviscid codes-NavierStokes codes.

End of FY 1975

- o Complete downstream PERF development.

Mid-FY 1976

- o Complete static stability and performance investigation of Pioneer Venus probe configuration.
- o Establish boundary-layer transition criteria with ablation.
- o Establish static stability and performance for Saturn entry probe.

End of FY 1976

- o Complete ablation product radiative property measurements.
- o Complete STAR forebody flow analysis with radiation, equilibrium or nonequilibrium chemistry and angle of attack effects.

NEED AND RELEVANCY:

Exploration of the solar system is one of the primary objectives of the NASA because it provides the opportunity to dramatically improve man's understanding of three fundamental scientific problems; the origin and evolution of the earth, sun, and the planets; the origin and evolution of life; and the dynamic processes that shape the terrestrial environment. Much of the information sought can only be gained through measurements obtained in the atmospheres and on the surfaces of the planets and from the return to earth of samples from celestial bodies. Consequently, the development of a strong base in planetary entry technology is an essential prerequisite to solar system exploration. This technology base must be available to support, in a timely manner, the OSS mission model (see "The 1973 Payload Model: Space Opportunities 1973-1991") which anticipates probe missions to Venus (launch in 1978), Uranus (launches in 1979 and 1981), Saturn (launch in 1980), and Jupiter (launch in 1984). The requirements for minimum mission costs and maximum science return coupled with long trip times rule out "cut and try" engineering and dictate that a high probability of success be guaranteed prior to final commitment to a mission.

The planetary entry technology objective is of primary relevance to the Agency goal to gain fundamental scientific knowledge and to the OAST focus on spacecraft and entry systems technology--deep space exploration systems--and of applicable relevance to the OAST focus on basic research.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	89	90	85	80	72	72
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	889	890	1240	1250	1255	1250
IMS	1293	1376	1045	950	865	865
TOTAL R&D	2182	2266	2285	2200	2120	2115
R&PM Resources	2850	2814	2595	2360	2145	2130
TOTAL VALUE	5032	5080	4880	4550	4265	4245

b. RTOP Resources

			NEGOTIATED		BEST ESTIMATES			
			FY 74		FY 75		FY 76	
	RTOP Number and Title	Center	Net $ (K)	Man-Power	Net $ (K)	Man-Power	Net $ (K)	Man-Power
(502-07-01) (502-27-01)	506-26-20 Planetary Probe Design	ARC	196	18	220	18	220	17
(502-07-01) (502-27-01)	506-26-20 Planetary Probe Design	LaRC	293	61	245	60	480	55
(502-27-01)	506-26-20 Planetary Probe Design	JPL	400	10	425	12	540	13
	TOTALS		889	89	890	90	1240	85

c. Crosswalk Resource

1. 100% of resources of primary relevance to the specific OAST focus of spacecraft and entry systems technology.

2. 20% of resources of applicable relevance to the specific OAST focus on basic research.

TYPE OF SPECIFIC OBJECTIVE: XX DISCIPLINE
____STUDY____SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Entry Technology: Aerothermodynamics - J. E. Greene; P. A. Cerreta

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide aerothermodynamic technology support to the Shuttle Program Office and its contractors as required in the design development and verification of the most efficient system within program constraints through independent analysis and solution of problem areas and through utilization of wind tunnel and other simulation facilities. Specific targets are:

- o By late FY 1975 provide in time for CDR a flow field computer code to simulate on ILLIAC IV the hypersonic nonequilibrium flow over the windward surface and certain isolated leeside surfaces of the space shuttle orbiter.

- o Provide experienced personnel and facility support for in-house and contractor generator action items and test requests as required during the design, development and verification of the space shuttle aerodynamic configuration.

APPROACH:

The unique facilities and expertise available in the OAST Research Centers constitute the most comprehensive capability for shuttle aerothermodynamic testing in the United States. Experienced personnel will continue active participation in appropriate JSC shuttle development support working groups and engineering coordination panels in which specific problem assignments will be generated. Wind tunnel and arc-jet tests in support of project office requirements and contractor development and verification of the shuttle aerodynamic configuration will be carried out by the Ames and Langley Research Centers. It is expected that the resources of these Centers will be required throughout the shuttle development and early phase of operation; however, required levels of effort will start to decrease after FY 1975.

Areas of Center emphasis are:

- o Application of unique aerothermodynamic, analytical and experimental capability will be applied to shuttle development problems as required. Specific areas of activity to be carried out in Ames and Langley Research Centers will include aerodynamic performance, stability and control, orbiter/launch vehicle separation, plume simulation and dynamic stability.
- o In support of the orbiter thermal protection system, analytical and experimental work by Langley and Ames will be undertaken to determine shuttle aerodynamic heating. Emphasis will be placed on determining lee-side heating and the effects of TPS tile orientation and size, and the complex heating pattern associated with gap flow and reattachment on the surface.
- o Unique capabilities at Ames will be utilized to develop inviscid flow computer codes that numerically simulate the complete three-dimensional windward surface flow over the shuttle. The generation of viscous boundary layer codes which use inviscid flow as input to predict aerodynamic heating will be included.

Major milestones of space shuttle test support are:

Early FY 1975	-	Complete aerodynamic and heat transfer measurements on shuttle configuration. Complete system studies and recommend means of expanding allowable C.G. envelope.
Mid FY 1975	-	Complete initial phase of three-dimensional windward surface flow computer codes. Establish effects of Mach number, Reynolds number and specific heat ratio on aerodynamic characteristics at hypersonic speeds. Support plume technology assessment and provide plume test capability.
Late FY 1975	-	Complete analysis of effects of temperature, pressure and non-uniformities on heating to RSI tiles and gaps. Provide the necessary aerothermodynamic data and analysis to allow successful accomplishment of orbiter Δ PDR.

FY 1977 - Verify aerodynamic characteristics of the final orbiter design.

Post FY 77- Provide analysis and test support for development problems as they arise.

NEED AND RELEVANCY:

The Agency is committed to developing a space shuttle system that can transport crew, passengers and cargo to low earth orbit at greatly reduced cost as compared to present systems. Current and future aerothermodynamic work will be directed toward contractor-requested wind tunnel tests and laboratory and computer studies which support shuttle final design and system verification.

Space shuttle test and support is of primary relevance to the Agency goal of routine and economic space transportation and facilities and to the specific OAST focus of shuttle technology-low-cost exploitation of space; and of applicable relevance to the specific OAST emphasis on technology for military needs.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)	147	111	72	54	50	50
FUNDING REQUIREMENTS (K,$)						
Net R&D	359	525	755	510	420	420
IMS	2135	1956	1045	777	733	733
TOTAL R&D	2494	2481	1800	1287	1153	1153
R&PM Resources	5251	3973	2582	1925	1816	1816
TOTAL VALUE	7745	6454	4382	3212	2969	2969

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
(502-37-01) 506-26-30 Shuttle	ARC	247	71	240	48	265	28
(502-37-01) 506-26-30 Shuttle	LRC	112	76	285	63	490	44
TOTALS		359	147	525	111	755	72

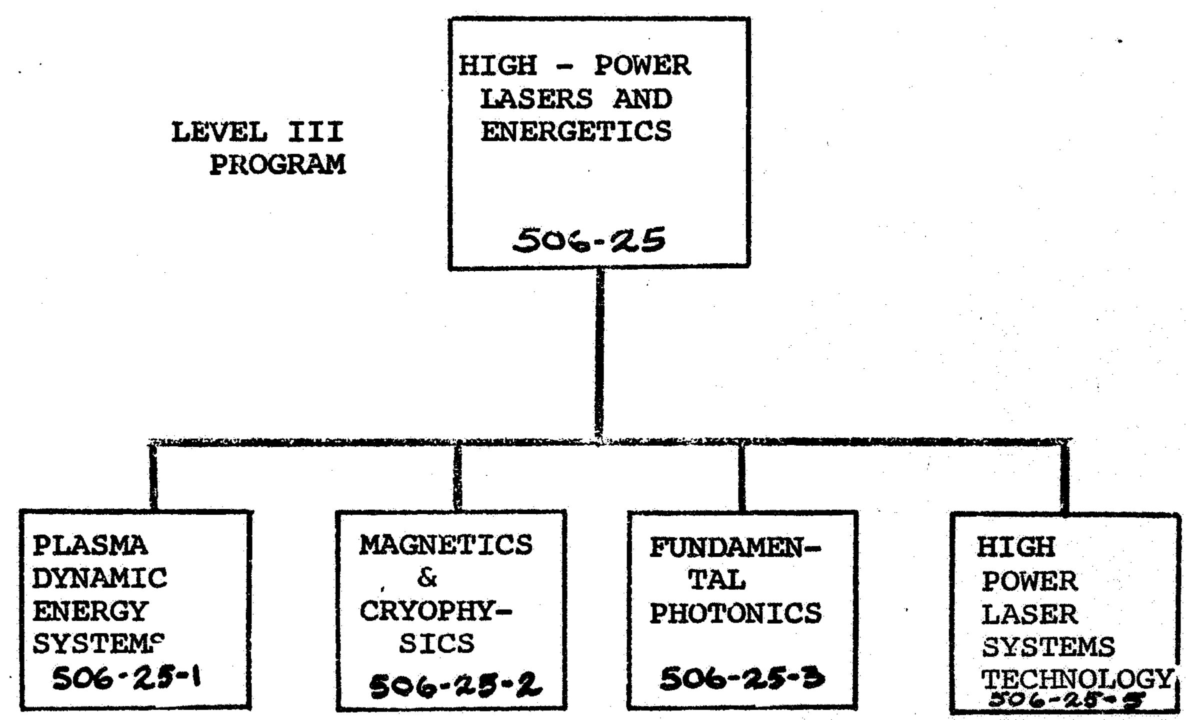
c. Crosswalk Resource

1. 100% of resources of primary relevance to the "specific OAST focus" of shuttle technology.

2. 100% of resources of applicable relevance to the "specific OAST focus" of DOD support.

HIGH-POWER LASERS AND ENERGETICS WORK BREAKDOWN STRUCTURE

LEVEL III
PROGRAM



LEVEL IV SPECIFIC OBJECTIVES

Program Objective

Provide, through basic research and experimental engineering, the major advances in power generation and transmission needed for advanced capabilities in space and for long-range energy needs on Earth. We will investigate:

- Plasmadynamic energy systems which may yield compact, light-weight power systems for space missions.

- Magnetics and cryophysics for new levels of performance in low-loss high-field-strength magnets which apply to motors, generators, transmission lines, and basic physics research.

- Fundamental photonics research on the radiation processes in nuclei, atoms, and molecules which is the basic data needed to understand natural processes in the atmosphere, in energy systems, and in lasers.

- High Power Lasers Systems to determine their potential for transmitting energy over great distances in space to provide for major reductions in cost for space power and propulsion.

Fundamental data on physical processes and basic research in energetics leads the way to novel concepts and new technology having direct benefits for energy needs in space and in maintaining the technical leadership of the U.S. The lasers being investigated have promise for space and are of value to laser-fusion, isotope separation, and photo-chemical processing.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)	150	150	150	150	150	150

Manpower

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D	3,000	3,000	3,500	4,000	4,000	4,000
IMS	1,500					
TOTAL R&D	4,500					
R&PM Resources	3,000					
TOTAL VALUE	7,500					
EST. NET COSTS	2,000					

OBJECTIVE DOCUMENTATION

TITLE: Plasmadynamic Energy Systems

TYPE OF OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Energetics and Lasers

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To establish the knowledge required to produce, confine, and utilize plasmas for advanced power and propulsion systems of potential importance to NASA, and to understand the fundamental physical processes involved in plasmadynamic energy systems.

Targets:

- o Demonstration of closed loop MHD power conversion at plasma power densities 10--100 greater than in previous tests, and at a temperature of 2100K completed in FY 1974. Work phasing out in early FY 1975.
- o Test combustion-driven (H_2-O_2) MHD power generation suitable for flight applications (high power density--100 w/cm^3, short length, high magnetic field) by FY 1977.
- o Investigate processes for producing thrust and power from high-temperature (fusion) plasmas. Major investigations currently planned should be complete by FY 1977-1978 time period.

APPROACH:

Research on plasmadynamic energy systems in NASA is conducted entirely at the Lewis Research Center and involves two major topics: MHD power conversion and high-temperature (fusion) plasma research. The current program is an outgrowth of more than ten years of in-house research in the field of plasmadynamics and, for certain projects, utilizes experimental equipment and apparatus which has been acquired during the past several years.

In MHD power conversion research, the world's largest closed-loop MHD experiment has been designed, built, and operated at conditions that might be achieved with high-temperature nuclear reactors expected as an outgrowth of nuclear rocket technology. Using Argon gas seeded with Cesium, this MHD-generator loop uses electrical resistance heating to simulate a reactor in reaching a temperature of 2100K. Research objectives are achieved in FY 1974, and the work is to be phased out in FY 1975.

Continuing MHD-research program is directed toward a capability of generating power in small-size, light-weight systems suitable for flight applications. A new combustion-driven MHD experiment has been started using existing magnet and rocket facilities. A combustor is being developed for stoichmetric burning of hydrogen and oxygen, and a means to seed the hot gases with cesium hydroxide to increase electrical conductivity is being provided. This experiment will use strong magnetic fields in a neon-cooled, cryogenic magnet in order to achieve a high power density ($\gtrsim$ 100 w/cm^3).

The approach being taken in high-temperature (fusion) plasma research is to first establish a capability at the Lewis Research Center to produce fusion-like plasmas for further research into energy conversion, thrust production and fusion reactor technology. Included in this approach is a recognition of the strong program of the AEC in controlled fusion research.

An in-house program permits NASA to assess and extend progress in fusion research for NASA needs and provides a means for the flow of NASA technology into a program of major significance to future national energy needs.

There are two major devices for conducting high-temperature plasma research at LeRC: the Bumpy Torus and the Superconducting Magnetic Mirror Apparatus (SUMMA).

As the names indicate, the Bumpy Torus uses a closed toroidal magnetic field for plasma confinement; whereas the SUMMA is an open-ended magnetic mirror device. In both experiments, D. C. power is supplied for plasma heating. One of the key goals in this research is to understand the processes by which D. C. power is converted to high temperature ions as observed in previous similar experiments.

The Bumpy Torus experiment became operational in December 1972, when the plasma was produced therein for the first time. After some exploratory test runs the Bumpy Torus is being equipped with a new higher-voltage (100Kv) power supply and new or improved instrumentation for diagnosis of the plasma heating phenomena.

When these improvements are complete, performance of the Bumpy Torus will be measured and compared with theory to determine the confinement time, temperature and density properties of its plasma. The experiment should continue during FY 1975 and 1976.

Experiments in the SUMMA device will continue through FY 1975 and data should be available on fusion-like plasma, i.e., at a temperature of 5Kev or 50,000,000K and a density of 10^{14} ions per cubic centimeter.

After the operating characteristics of the Bumpy Torus and SUMMA devices are known, the research on high-temperature (fusion) plasma can follow several paths which are now under study. Among the possible plasma research areas to be considered are direct conversion of ion energy to electrical power, fusion-fragment heating of plasmas, plasma deflection to produce thrust, laser heating of plasmas, and fusion fuel injection problems. Certain fusion reactor engineering problems could also be studied; among these are heat transfer from the plasma, material damage by 14 MeV neutrons released by the fusion reactions, and tritium breeding.

Major Milestones for the Plasmadynamics Energy Systems Research Program are:

- FY 1975 Cesium-seeded, Stoichiometric H_2-O_2 Combustor demonstrated.
- FY 1975 initial plasma experiments in SUMMA and Bumpy Torus have produced keV ions and fusion neutrons. In FY 1975 prove thermalization of keV ions at increasing densities.
- FY 1975-1976 define and initiate experiments using fusion-like plasmas for NASA objectives.
- Early FY 1976 complete first high-field MND-generator test.
- Late FY 1977 demonstrate MHD program goals; high power density, high enthalpy extraction per unit length.

NEED AND RELEVANCY:

The significance of the research conducted in Plasmadynamic Energy Systems is its potential to provide new capabilities for missions in aeronautics and space because of the very high energy density possible in plasmas. Therefore, generation and utilization of energy in the plasma state affords prospects for innovation in power generation and space propulsion. MHD-generators in the high-power range may provide light-weight power systems suitable for military aeronautical and space applications. In addition, these generators may also contribute to producing low-cost power for terrestrial needs from natural and artificial fuels, and, because of high efficiency, represent superior fuel utilization in conjunction with reduction in thermal and atmospheric pollution.

In the long term, fusion energy sources appear to offer the ultimate in performance potential for space missions extending great distances into space.

The prospects in this case are a propulsion system with a specific impulse in the 10,000-second range and a low specific mass which will allow spacecraft to voyage throughout the solar system with moderate trip times. In addition, the NASA research on high-temperature plasmas will aid in the achievement of fusion power on earth.

OBJECTIVE: PLASMADYNAMIC ENERGY SYSTEMS
(506-25-01, previously 502-10-01)

LeRC

RESOURCES	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	31	40	40	40	40	40
FUNDING REQUIREMENTS (K Dollars)						
Net R&D (NOA)	20	100	100	100	100	100

OBJECTIVE DOCUMENTATION

TITLE: Magnetics and Cryophysics

TYPE OF OBJECTIVE: X DISCIPLINE ____ STUDY ___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Research Division

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To achieve intense magnetic fields in large volumes with a minimum of mass and power required; to conduct research on superconducting materials and processes; and to study the effects of low temperatures and intense fields on materials and devices of significance to space applications.

Targets:

- o Demonstrate the capability for stable operation at high current density in superconductive devices (magnet, motors generators) at temperatures of 4K (liquid helium). Current approach: to produce twisted filamentary structure with Nb_3Sn ribbon and tests in large-scale experiments in FY 75-77.
- o Demonstrate operation of a neon-cooled cryogentic magnet (25-35K) at a field strength of 30T. By FY 1978 to provide a substantial advance in magnet technology designed specifically for use with an MHD generator at a field strength of 5--7T by the end of FY 1978.

- Search for superconductors with high values of critical temperature, current density, and field strength. In the near term, extend the temperature range over which excursions due to local heating can be tolerated in superconducting magnet. For the long range, discover useful superconductors to operate at temperatures associated with liquid hydrogen or higher-temperature cryogens.

- Demonstrate during FY 1975 the principles of a magnetic refrigeration system (1 watt power level) operating between 20K and 4K to establish an efficient means to cool superconductors for a wide range of applications.

- Evaluate the potential for magnetic cooling using ferromagnetic materials at temperatures up to room temperature and demonstrate a small-scale air-conditioning or heat-pump machine by FY 1976.

- Explore the usefulness of the unique facilities for high magnetic field strengths, large volume and cryogenic environments for conducting relevant basic physics research.

APPROACH:

Theoretical, experimental, and development work will be performed, aimed at the attainment of high magnetic field strengths in large volumes with minimum weight and power consumption, for space and earth-bound propulsion and power applications. Special emphasis will be on superconductive and cryogenically cooled magnets because of their high current density and low power consumption. New mechanical designs for magnets as well as for the basic conductor itself will be developed. Because refrigeration is a major capital and operating cost component of very low temperature systems, the development of higher critical temperature superconductors and of more efficient refrigeration systems will also be studied.

- Superconductive intermetallic compounds (e.g. Nb_3Sn) have the highest values of critical temperature, field and current. Constraints arising from physical properties (especially brittlesness) and available methods of making the compounds limit the forms these materials may take and have resulted in conductor geometries that produce severe instability and remnant field problems. Fine filamentary structure combined with conductor twist have proved to be effective in reducing or eliminating these problems in the ductile alloy superconductors. A method has been devised to achieve twisted, multifilament characteristics with Nb_3Sn ribbon and development of the means to produce the material in long lengths has been initiated. Sufficient material will be produced in FY 75 to wind magnet coils by FY 76 large enough to demonstrate the effectiveness of the techniques in providing stable operation at high current density in superconductive devices.

- The present liquid neon cooled magnets (producing up to 18.5 T field strength) are cooled by nucleate boiling in a free convection mode, which necessitates a considerable openness in the coil structure to permit adequate coolant circulation. The fraction (presently 38%) of the winding which is actually conductor could be approximately doubled, and the current density could be raised if non-boiling, forced-convection heat transfer is used and if the amount of structural support for the conductor is varied to match stress levels in various magnet regions. Preliminary designs and cooling tests indicate 30T can be achieved in a 3" design bore solenoid with about 1 MW power consumption. Detailed designs completed in FY 74 permit coil tests in FY 75, entire magnet fabrication and facility modifications in FY 76 and 77 and magnet tests in FY 77 and FY 78.

- Various MHD generator magnets have been designed and built for U.S. and European applications. Only partial success can be claimed for these magnets. Failure to attain design field values has generally been caused by conductor motion due to the high mechanical stress levels and the difficulty of providing adequate support. Significant advanced in MHD power generation can be achieved with higher field strengths and larger volumes, but the conductor support problems must first be solved. Design studies of the structural requirements and means of solution will be made and an MHD magnet of useful size and having a field strength of 5 to 7 tesla will be constructed.

- The search for superconductive materials having high values of critical current, field and temperature has not resulted in major advanced in the past 10 years. The usefulness of the superconductive materials available has nevertheless been greatly extended by significant advanced in composite conductor forms and in winding techniques. Further substantial advances are still possible even without the as-yet-elusive breakthrough in improved critical values. Efforts to improve performance through better stabilization, improved strength and lighter weight will continue. In a joint program with JPL, intercalated compounds such as alkali metals in MoS_2 are exhibiting interesting superconductive characteristics which may lead to increased understanding of the basic physical phenomena involved. Other intercalate systems will be investigated followed by hydride systems.

- A nominal 1 watt cooling power (at 4K) magnetic refrigerator has been constructed. The device, containing a concentrated rare earth salt, $Dy_2Ti_2O_7$, will produce refrigeration by performing a magneto-thermal cycle, one leg of which is an adiabatic demagnetization from about 20K to 4^oK. In principle the cycle can approach Carnot efficiency and would be a desirable replacement in the 4-20K range for the Joule-Tompson effect, which is irreversible and hence inefficient. A 10 watt unit will be designed (FY 75) upon successful testing of the 1 watt device.

- A simple molecular-field analysis of the magnetocaloric effect and the isothermal magnetization process in ferromagnetic materials near and above their Curie points has shown magnetic heating and cooling effects of a few tens of degrees K are possible near room temperature with appropriate materials (e.g. the element Gd). Concepts of suitable mechanical embodiments of the principle in a practical device to perform air conditioning or heat pumping have been developed. Further concept development and measurements of magnetic entropy of Gd as a function of temperature and field is FY 74. Mechanical design and construction of a small air conditioner or heat pump will be done in FY 75 and testing will follow in FY 76.

- The 4" bore (~8T) water-cooled magnet, the 2½" bore 11T superconducting coil, the 18T cryomagnet and the 15T, 6" bore superconducting coil will be used for a variety of basic research efforts. The following will be included: . magnetization and magnetic entropy measurements on mixed rare earth oxides, garnets, rare earth hydrides, and alloys of rare earth metals, . critical constant measurements of superconducting intercalate materials and superconducting hydrides, . galvanomagnetic property measurements on various semiconductors and semimetals.

Major milestones of the Magnetics and Cryophysics research are:

Late FY 75 - Single coil tests of 30T magnet.

FY 76 - Tests of twisted filamentary Nb_2Sn ribbon in magnet. Construct room temperature magnetic cooling device.

FY 77 - Complete 30T magnet. Demonstrate efficient and economical magnetic refrigeration.

FY 78 - Test 30T magnet.

NEED AND RELEVANCY:

Larger, higher field, lighter, more reliable, and cheaper magnets are needed for use in space propulsion and power schemes based on MHD or on fusion. Research in this area is directed at improving fundamental parts of the magnet system, e.g. the SC material itself, the magnet structure system, and the refrigerating system to keep it cold. In the context of the energy crisis, greater significance is added. The development of MHD magnets (and the supporting fundamental work) is significant because of the increase in overall generating efficiency when the MHD topping cycle is used. Other basic components of the generating and distribution network (generators and transmission lines in particular) will likely be superconducting in the future to overcome size limitations and losses that occur in present practice. The development of a high efficiency magnetic refrigerator would reduce capital and operating costs of all superconducting systems, especially the transmission line. More efficient refrigeration at higher temperature could impact costs of tonnage air separation plants, thereby affecting heavy industries like steel, and could provide substantial economies in home and office heating and cooling.

2/15/74

OBJECTIVE: MAGNETICS AND CRYOPHYSICS

(506-25-02, previously 502-10-02)

LeRC

RESOURCES

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	11	12	15	15	15	15
FUNDING REQUIREMENTS (K Dollars)						
Net R&D (NOA)	100	100	100	100	100	100

TITLE: Fundamental Photonics

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE ___ STUDY
___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Research Division - Dr. Thom

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide basic data on molecular, atomic and nuclear reaction cross sections, reaction rates and electromagnetic radiation emission and absorption spectra in plasmas, gases, liquids and solids in support of a broad range of NASA applications in propulsion, power, lasers and space and atmospheric physics. Specific targets are:

- Determine ion - ion and ion-neutral collision cross sections for production of excited states, including charge transfer collisions, and determine rates for reactions which depopulate lower lasing levels. Complete charge transfer reaction studies for all noble gas ions and CO_2, N_2O, CO, N_2, O_2, and NO by FY 1975. Complete the following reaction studies for depleting ground state ions in a lower lasing level by FY 1975: CO_2+, CO+, N_2+, O_2+, and NO+ with H.

- Determine atomic and molecular energy levels, metastable states, and electron impact cross sections for Cu vapors, rare gases, and N_2, CO, CO_2, and H_2 as potential lasants. Complete during FY 1975. Expand this research through FY 76 to include other metal vapors, and possibly uranium and UF_6.

- Investigate the feasibility of various concepts for visible, UV, and x-ray lasers.

- Investigate fundamental characteristics of fissioning uranium plasmas for the purpose of determining feasibility of methods for directly converting nuclear energy into e.m. radiation, laser power, or work.

- o Investigate nuclear pumped iodine and xenon lasers in FY 1975. Measure fission-fragment and photon-induced **chemical** kinetics of $^{238}UF_6$ and $^{235}UF_6$ through FY 1977.

- o Evaluate the possibility of stimulated emission radiation from nuclear energy levels excitation for gamma ray lasers. Approach the study of nuclear levels excitation in the realm of nuclear Zeeman levels. Achieve maser action by the end of FY 75.

APPROACH:

Research on fundamental photonics in NASA is conducted primarily at the ARC, LRC, LeRC, and JPL. Emphasis is placed on the basic principles of radiative energy exchange with matter, which is an outgrowth of previous molecular, atomic, nuclear and plasma physics research. The physics of such energy exchange is the lead for generating coherent radiation at broad ranges of frequency, high power, and high efficiency, the conversion of such radiative power into electricity, or other forms of work and, ultimately, the direct conversion of nuclear energy into electromagnetic radiation.

- o The unique capabilities of the JPL electron impact spectrometers will be utilized to determine the cross sections for electron-molecule and electron-atom collisions in the range of 0.1 - 100eV energy that are important for electric discharge lasers and certain plasma devices. Near term targets are for metallic vapors (Cu, Hq, Pb, U), the rare gases, and N_2, CO, CO_2, H_2, and possibly U and UF_6. In addition, search for metastable states and for forbidden transitions will be continued which cannot be measured in conventional spectroscopy. The measurements will be extended to metastable targets, to superelastic scattering, and to electron-photon scattering.

- o The unique JPL Ion Cyclotron Resonance Apparatus will be employed to measure low energy charge transfer reactions at ion-neutrals collisions resulting in excited levels. Also, effects will be studied resulting in depletion of lower lasing levels. Near term targets are the interactions of rare gas ions, such as He^+, Ne^+, Ar^+, Kr^+, and Xe^+ with molecules such as CO_2, N_2O, CO, N_2, O_2, NO and UF_6.

- In laser kinetics research, experiments will be conducted in a discharge tube to investigate the rates of excitation and radiative deexcitation in various gases that show promise for population inversion in lasants for visible and UV radiation. Theoretical and experimental research will be conducted on a superfluid helium vacuum UV laser concept. This will be aided by experimental and theoretical development of distributed feedback techniques which promise to replace the UV inefficient mirrors as well as aid other IR, visible, UV, and x-ray laser systems. Recombination of electrons with ions having inner-shell vacancies will be investigated. Possibilities of UV and x-ray lasers will be studies involving multi-photon absorption of low-frequency, high power pulses in dense plasmas. The ARC gigawatt glass laser facility will be employed.

- A fissioning plasma consists of neutral and ionized uranium atoms which are exposed to fluxes of high energy fission fragments. Upon collisions with such fission fragments, the gas atoms, or ions, become excited and radiation is emitted. Near term research targets of current fissioning plasma research include: the demonstration of population inversion and subsequent laser action in fission fragments induced lasants in a research reactor, the demonstration of fission fragments induced non-equilibrium optical radiation from UF_6 in a research reactor, the emission of fission fragments induced UV and x-ray radiation from an enriched uranium plasma sample in the LRC plasma focus, and measurements of K-shell heavy particles excitation cross sections caused by fission fragments impact in the LeRC modified cyclotron facility.

- In nuclear Zeeman maser research, a near term target is to improve methods of chemical induced nuclear polarization and to determine their applicabilities to increase the population difference of the nuclear Zeeman levels above their thermal equilibrium value. Simultaneously, measurements are to be made of energy level increases in varying magnetic fields.

- Novel concepts of laser generation and laser power conversion will be explored, such as the reversible photon engine, and population inversion of isomeric nuclear states.

Major milestones of the Fundamental Photonics research are:

Late FY 75	-	Electron Impact Spectroscopy: electron-uranium vapor impact measurements.
FY 75	-	Ion Cyclotron Resonance apparatus: reaction rates for charge transfer from He_+, Ar_+, Kr_+, and Xe_+ to CO_2, N_2O, CO, N_2, O_2, and NO completed.
Mid FY 75	-	Preliminary tests of HeII vacuum - UV laser.
FY 75-76	-	Demonstration of nuclear pumped high pressure laser; demonstration of nuclear induced optical radiation from cold UF_6 mixtures.
FY 75-77	-	Measurements of UV and x-ray radiation from fissioning plasma samples.
Mid-FY 75	-	Demonstration of chemical-induced nuclear polarization of nuclear Zeeman maser and of energy level increase by magnetic field.

NEED AND RELEVANCY:

The Fundamental Photonics research is for direct support of the High Energy Laser, the Plasma Core Reactor and Plasmadynamics research programs, whose relevancies to NASA are described in the respective Objective Documentations. This work is also of primary relevance to the "specific OAST focus" of "basic research" responding to the OAST emphasis of "engineering science and innovation" displayed in the Space Matrix.

Fundamental photonics research is the basis for significant advances of scientific understanding of many means for the generation, the transmission, the conversion and the utilization of power. In a broad view, fundamental photonics research represents an analogous scientific endeavor to the previous most rewarding electronics research.

One should realize that, in electronics, the electrons are the major carriers of energy and the media for energy conversion and transmission. In Photonics research, means are sought to employ photons wherever the nature of photons may result in advantages. This is basically possible since the advent of lasers. Coherent radiation at a desired frequency and intensity enables man to manipulate photon fluxes under similarly controlled conditions as electron fluxes at predicted currents and voltages. Fundamental laws of physics tells us that photons and electrons (and other matter particles) are complementary elements of the structure of nature.

We expect, therefore, that photonics research for approaching a parity of photonics and electronics will result in innovations which, ultimately, may be beyond our present capabilities of prediction. Research in and for space involves high energy levels, and it appears, therefore, that the photonics--electronics synthesis will be most rewarding for NASA objectives. However, immense benefits for terrestrial applications can be visualized, particularly on the background of forthcoming energy and economic needs.

Examples are: (a) the direct conversion of nuclear energy into optical radiation for propulsion and power in space at drastically reduced specific mass, (b) terrestrial power at greatly increased efficiencies, (c) means of photo-chemical processing, (d) power transmission at almost unlimited power density, and (e) higher speed miniaturized computers and integrated optics elements.

2/15/74

OBJECTIVE: FUNDAMENTAL PHOTONICS
(506-25-03, previously 502-10-03)

HQ, ARC, LaRC, LeRC and JPL

	FY 74		FY 75		FY 76		FY 77		FY 78		FY 79	
Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power
ARC	190	19	200	20	220	20	220	20	220	20	220	20
LaRC	130	6	250	6	250	6	250	6	250	6	250	6
LeRC	20	7	95	7	110	7	110	7	110	7	110	7
JPL	641	14	725	14	800	14	800	14	800	14	800	14
HQ	234	-	89	-	120	-	120	-	120	-	120	-
TOTALS	1215	46	1359	47	1500	47	1500	47	1500	47	1500	47

OBJECTIVE DOCUMENTATION

TITLE: High Power Laser Systems Technology

TYPE OF OBJECTIVE: _X_ DISCIPLINE ___ STUDY ___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Research Division

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To evaluate the potential of high power lasers for NASA missions and applications, to provide the research and technology base needed to make this evaluation, and to demonstrate the potential utility of high power lasers for selected applications. Achievement of this objective involves an integrated program directed to provide needed information within a 5-year time period.

Targets:

- o Evaluate the technical problems in closed-loop, CO_2 laser systems for operation at high power levels for long periods of time during FY 75.
- o Investigate the characteristics of potential laser concepts to permit the selection of optimal lasers in terms of efficiency, power capability, and the proper wave length for power transmission and energy conversion through FY 76.
- o Generate and investigate novel means to convert laser beams into thrust or into electricity with an efficiency greater than 50% through FY 75-77.
- o Establish the limits and potential for transmitting laser beams through atmospheres under all conditions by FY 77.

- o Complete evaluations of applications for laser power systems to assess technical progress, to provide technology goals, and to determine benefits of lasers to prospective NASA missions by FY 79.

APPROACH:

In a recent NASA study, the status of laser technology and future laser developments were evaluated in respect to potential missions in space. With only present laser technology considered, the study showed that high power lasers would not be useful for power and propulsion in NASA missions; however, it was also apparent that projections of future laser technology could make a major change in the prospective utility of high power lasers for NASA. From these findings, a high power laser program was established which attempts to extend the science and art of high power lasers and other elements of a complete system in the direction needed for space applications. Five years has been set forth as a reasonable time to spend in this program.

The most promising high power laser application is long range transmission of energy in space. Major improvements in technology are required to make the idea practical and cost effective. Lasers must be made highly efficient, long operating durations with high reliability are needed, and the lasers should recycle the lasing medium to reduce total mass required for operation in space. For long ranges, short wave length lasers and large optical components are needed. A complete power transmission system also requires a means to utilize the laser beam at the receiving end either to generate electrical power or to produce thrust for propulsion with high efficiency.

On the basis of existing technology, power transmission by a laser beam for a distance of 1000 kilometers with an overall efficiency of one percent could be accomplished. Near term research and technology targets could extend this range capability to over 100,000 kilometers and increase overall efficiency to approximately 10%.

Further improvements in power transmission may be in the breakthrough category; however, there are schemes which may increase the effective range to 1 AU and provide overall efficiencies of 20-40 percent. Thus, there is a substantial improvement to be gained over existing technology which is the basis for the detailed approach followed in this program.

(a) Laser System Technology - This portion of the program treats the overall laser power transmission system to analyze applications and determine technology requirements. To investigate the technology problems of a laser beam generator for power transmission, a pilot laser system is being constructed at the Lewis Research Center. The pilot laser system is a carbon-dioxide laser; it is a closed loop system; and it employs electrical pumping of the lasant. Planned to be operational by October 1975, this pilot laser system affords a flexible tool for conducting investigations of laser cavity designs, pumping methods, materials, optics, and long term effects such as contamination and life-limiting features. Work in the area of general systems evaluation with the pilot laser and by means of systems analysis and basic research should continue through mid-FY 1976, at which time enough knowledge should be available to permit definition of a program of selected technology--selected as being best suited to potential NASA applications. By mid-FY 1978, after two years of effort on selected systems technology, the program would reach the major decision point regarding the continuation of the program into prototype systems technology for a specific use.

(b) Laser Device Research - While laser system technology is based on the well-known carbon-dioxide system, laser device research has the purpose of exploring laser concepts which hold the promise of high efficiency and short wave length. It will be carried far enough to identify essential characteristics needed for their consideration in a power transmission system. Laser device research is conducted at several NASA centers where unique capabilities and interests exist. At the

Ames Research Center, research is conducted on an electrogasdynamic laser using carbon monoxide a molecule that lases with a wave length of 5 microns compared to 10.6 microns for CO_2. ARC will also use an arc-heated gas supply to complete studies needed to optimize CO_2 lasers and then move into studies of visible lasing from carbon vapor.

The Jet Propulsion Laboratory is conducting research on copper and other metal vapors which produce visible laser beams. In addition, JPL has begun research into the vacuum ultraviolet laser field using electron-beam pumping of high pressure xenon.

Lewis Research Center has begun research on resonant-charge exchange lasers having a range of wave lengths employing equipment and knowhow from their programs on plasma propulsion. LeRC will also monitor progress in this entire area to perform appropriate system and application studies needed to guide the overall program.

(c) Laser Energy Conversion Research - The approach in this area is to discover concepts which will convert laser beams to electricity with an efficiency greater than 50% and to thrust with a high specific impulse. For conversion to electricity, heat engine concepts are known to be practical but are not sufficiently efficient. As a consequence, converter research is devoted to novel concepts which take advantage of the monochromaticity or coherence of laser beams. Ideas currently being explored included Schottky-barrier, Gallium-Arsenide photovoltaic converters by JPL and point-contact diodes by ARC. New ideas are being sought through conferences and other contacts with the scientific community. In addition, converter systems will be studied by LeRC as part of their overall systems responsibility.

(d) Laser Atmospheric Transmission - In this area of research, the Langley Research Center is performing high-resolution spectroscopy of the atmosphere with tunable lasers, making linear absorption measurements with selected low-power lasers, and analyzing atmospheric transmission under a variety of conditions (altitude, humidity and direction). A detailed understanding of the potential for transmitting laser beams through atmospheres should result from this research which is complimentary to large scale efforts by the Department of Defense on the non-linear effects of atmospheres on the propagation of high-power laser beams.

Major Milestones of the High Energy Laser Systems Program are:

- o FY 75 closed loop electrically pumped CO_2 pilot laser system operational.
- o FY 75 continued search for "micro-window" laser transmission through the atmosphere by means of high resolution tunable lasers.
- o FY 76 definition of most promising laser power conversion concepts. Start feasibility demonstrations thereof.
- o FY 77 based on results of laser generator and laser power converter evaluations, conduct system analysis for in-depth determination of applications to NASA missions.
- o FY 78 decision point for go-ahead with technology development.

NEED AND RELEVANCY:

The significance of the NASA research and technology program in high power lasers is found in the potential it has for providing new capabilities for aeronautics and space missions. The capabilities of lasers to transmit power over great distances and at tremendous energy densities are certain to make a great impact on future NASA programs. In addition, such laser power transmission at an almost unlimited load per beam cross section may significantly improve the serious problem of future power distribution on earth. Results of laser power conversion research are expected to contribute to improved power utilization.

The approach followed by the NASA program will uncover these potential applications for lasers in space and aeronautics and will provide unique and useful laser technology relevant to their use by the Department of Defense, the Atomic Energy Commission, and industry. For example, the NASA emphasis on power transmission will spur the development of short wave length lasers so useful to all areas of application and will provide the endurance, reliability, and economy that would be required for laser-fusion power systems.

<u>RESOURCES</u>

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	36	35	41	41	46	46
<u>FUNDING REQUIREMENTS</u> (K Dollars)						
Net R&D (NOA)	933	905	1110	1160	1370	1370

2/19/74

OBJECTIVE: HIGH POWER LASER SYSTEMS R&T

(506-25-04) (LASER ATMOSPHERIC TRANSMISSION TECHNOLOGY)

LaRC

RESOURCES

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
LaRC	2	3	3	3	4	4
FUNDING REQUIREMENTS (K Dollars)						
Net R&D (NOA)	100	150	150	150	200	200

OBJECTIVE: HIGH POWER LASER SYSTEMS R&T
(HIGH POWER LASER DEVICES)

(506-25-05)

LeRC, JPL

RESOURCES

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
LeRC	25	23	26	26	28	28
JPL	5	5	6	6	7	7
FUNDING REQUIREMENTS (K Dollars)						
Net R&D (NOA)						
LeRC	400	300	400	450	500	500
JPL	250	250	300	300	350	350

2/19/74

OBJECTIVE: HIGH POWER LASER SYSTEMS R&T
(LASER ENERGY CONVERSION)

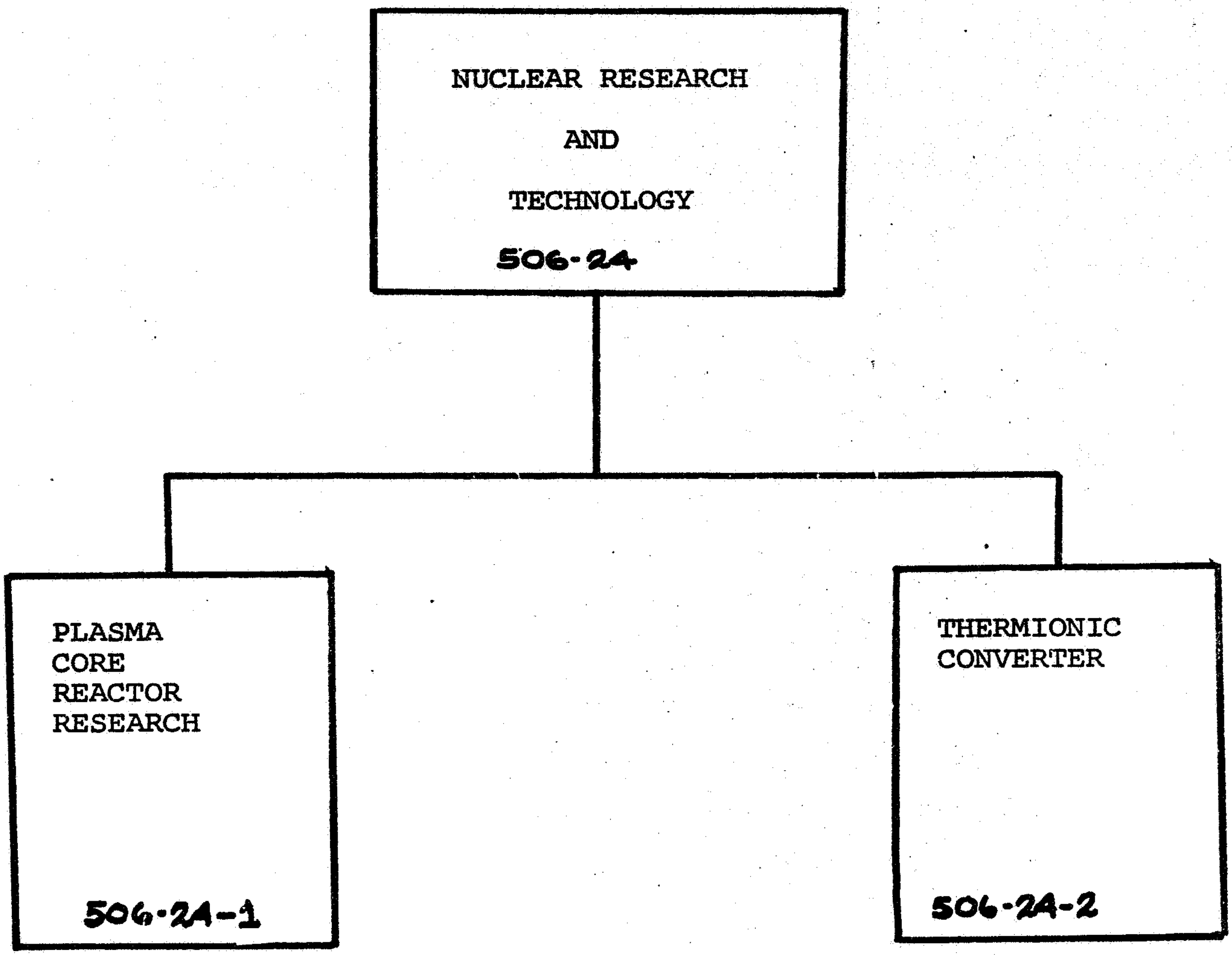
(506-25-06)

ARC, JPL

RESOURCES

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
ARC	1	1	2	2	2	2
JPL	3	3	4	4	5	5
FUNDING REQUIREMENTS (K Dollars)						
Net R&D (NOA)						
ARC	50	55	60	60	70	70
JPL	133	150	200	200	250	250

NUCLEAR RESEARCH AND TECHNOLOGY



LEVEL IV SPECIFIC OBJECTIVES

NUCLEAR RESEARCH AND TECHNOLOGY

Program Objective

Provide through basic research and experimental engineering the technological know-how for advanced utilization of nuclear reactor power in space and on earth.

- o Research on advanced, solid core nuclear fission reactors as multipurpose space power heat sources and on thermionic direct power generation for achieving high conversion efficiencies.

- o Plasma core reactor research for achieving gaseous nuclear fission energy sources at temperatures ranging from near room temperature to several 10,000K, and at power levels from near zero up to thousands of megawatts.

Fundamental physics and engineering components and systems data are generated as the stepping stones toward an advanced nuclear power technology in space and for utilization on earth, encompassing the potential of high specific impulse, high thrust propulsion in space, power for space stations and lunar bases, power for processing techniques and high energy lasers in space, and for more efficient and environmentally more acceptable power generation and utilization on earth.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower						
FUNDING REQUIREMENTS (K Dollars)						
TOTAL R&D	2.2	2.5				

OBJECTIVE DOCUMENTATION

TITLE: Plasma Core Reactor Research

TYPE OF OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEMS AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Research Division

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To establish the scientific knowledge and basic engineering know-how for gaseous core nuclear reactors operating at wide ranges of temperature and power, with the options of non-equilibrium optical radiation power output, and the recycling of nuclear fuel and actinides for the destruction of such actinides by fission and other nuclear transmutations.

Targets:

- Conduct critical $^{235}UF_6$ reactor experiments in FY 75 to determine the physics of gaseous cavity reactors.
- Demonstrate optical radiation emission from an essentially cool 1 kw power self-critical gaseous $^{235}UF_6$ reactor experiment in FY 76. Thereby establish proof of non-equilibrium excited states distribution in fission fragments induced plasmas.
- By increasing the power of self-critical gaseous $^{235}UF_6$ experiments during FY 76 up to 10kw, determine the ratio of optical versus thermal convection power output, depending on temperature and pressure. Obtain spectral power distribution depending on systems parameters.
- Define and conduct a follow-up series of self-critical gaseous core $^{235}UF_6$ and ^{235}U experiments that can demonstrate plasma core reactor operation over temperature ranges from near room temperature up to several 10,000K, at power levels from a few kw up to thousands of Mw, and that can emit sizable fractions of power in the form of non-equilibrium optical radiation.

APPROACH:

The program is to be conducted in two parts: (a) Research on reactor physics, the development of experimental hardware and the design, construction and conduction of nuclear self-critical experiments. Included is exploratory experimental research on UF_6 - fission fragments interactions involving the PARKA reactor facility. This part of the research will be managed and conducted by the Los Alamos Scientific Laboratory (LASL) under a NASA-AEC interagency agreement. Specific reactor experiments component research will be subcontracted by LASL with industry. (b) Basic research on the conversion of fission fragments energy into electromagnetic radiation, or heat, on fluid mechanics confinement of fissioning UF_6 and uranium plasmas, and on system analysis of plasma core reactor applications. This part of the research will be managed by the NASA Langley Research Center and will be conducted under industrial contract and University grants. Overall coordination of the program is provided by Headquarters Research Division.

Major Milestones of the Plasma Core Reactor Research are:

- FY 75 complete nucleonics computations and design for a near zero power self-critical $^{235}UF_6$ experiment, and demonstrate appropriate UF_6 handling capabilities.

- FY 75 start of near zero power self-critical UF_6 experiments. Analyze fission fragments induced optical radiation from the $^{235}UF_6$ fuel. Continue design studies and conduct component test for modification of the experiment for operation up to 10 kw power.

- FY 76 operate self-critical $^{235}UF_6$ experiment at 10 kw. Determine ratio of radiative power versus thermal power depending on pressure and temperature. Investigate the chemical stability of UF_6 depending on temperature. Test theoretical reactor physics predictions against experimental observations of reactivity feedbacks from poisoning effects of coolants, working fluids, and fluid mechanical confinement.

- FY 77 (additional funding needed) Increase the power of self-critical $^{235}UF_6$ experiment up to 100 kw. Start tests of applications: 1500-1800K gas turbine power, optical radiation in bands over wide ranges of frequency (IR to UV), optical or nuclear pumped lasers, photochemistry.

- FY 79-80 (additional funding needed) Start tests of a self-critical ^{235}uranium plasma experiment at 5Mw power and 5000K temperature.

NEED AND RELEVANCY:

The projected plasma core reactors are greatly superior to other nuclear energy sources:

(a) Temperatures ranging from near room temperature up to several 10,000K.

(b) Non-equilibrium optical radiation power output.

(c) Improved operational safety.

(d) Significant reduction of high-level radioactive waste production.

a. High temperature operation results in high efficiency power generation. At 1500-1800K (UF_6 reactor), a thermodynamic cycle, involving gas turbines, could exceed contemporary nuclear power generation efficiency. At 3000K MHD power generation becomes possible with even more increased efficiency. On earth, this results in improved fuel utilization and decreased rates of thermal pollution. For space power application, significant improvements of specific mass are possible. At about 10,000K, direct application to space propulsion is possible, at Isp approaching 5000 sec, and at thrust to engine weight ratio of about unity. No other projected scheme of propulsion is seen to be competitive for manned exploration of the near planets, or for heavy cargo lunar ferry operation.

b. Non-equilibrium radiative power from plasma core reactors is seen as the technologically most rewarding means of nuclear power utilization. While the reactor can remain relatively cool, for significant engineering ease and operational reliability, the emitted optical power can act at an equivalent temperature much higher than the reactor temperature. Photochemistry would be a dominant area of application, where, for example, the possible non-equilibrium UV-radiation from the plasma core reactor, at an equivalent temperature of 10,000K could effeciently be used in photolysis of water for economic hydrogen production. Non-equilibrium radiation may even be obtained in the form of a laser, or can be used for most efficient optical pumping of lasers. Applications for space power, power transmission in space, and for greatly advanced power generation and distribution on earth are obvious.

c. Plasma core reactors do not contain excess reactivity. Catastrophic power excursions, or meltdowns are impossible. Fuel circulation makes possible continuous on-site fission products processing and eliminates radioactive waste accumulation in the reactor and the needs of radioactive fuel rod transportation to processing plants. The continuous recycling of the gaseous nuclear fuel makes it possible to feed back into the reactor the radioactive actinides and to destroy them by fission or other transmutations.

2/15/74

OBJECTIVE: PLASMA CORE REACTOR RESEARCH
(506-24-01, previously 502-12-02)

HQ and LaRC

RESOURCES

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower (LaRC)	2	3	3	3	5	5
FUNDING REQUIREMENTS (K Dollars)						
Net R&D (NOA)						
LaRC	335	385	400	400	500	500
HQ	665	415	700	800	800	800
Totals	1,000	800	1,100	1,200	1,300	1,300

OBJECTIVE DOCUMENTATION

TITLE: Thermionic Converter Research and Technology Program

TYPE OF OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Research Division

STATEMENT OF OBJECTIVES, TARGETS, AND MILESTONE:

Objective: To establish the knowledge required to design and develop low-temperature thermionic converters suitable for a wide range of space and terrestrial power generation applications utilizing various heat sources including solar energy. This requires analytical and experimental studies required to understand the fundamental physical processes involved in the operation of thermionic converters, and systems design and applications studies to determine the merits of various heat sources and areas of application where thermionic energy conversion is cost competitive.

Targets:

- o Perform analytical and experimental studies of surface effects and plasmas, especially for the low-temperature operating region (900K). (FY 75)
- o Using above data, determine how to design a thermionic diode with reduced collector work function, collector double sheath, and plasma voltage drop. (FY 75-76)
- o Build and test thermionic converters to demonstrate successful operation at low-temperatures (900K) and high conversion efficiencies (15-30%). (FY 75-79)
- o Perform technology base evaluation. (FY 75)

- o Perform application studies. (FY 75-77)

- o Perform system design studies. (FY 75-77)

APPROACH:

In previous programs in the field of thermionic energy power conversion, the emphasis was to develop devices for potential missions in space. The design of the devices was constrained by requiring them to operate at high temperatures, usually in the core of a nuclear reactor, in order to minimize the radiator area required to reject the waste heat. This required that the thermionic converters be constructed of special refractory metals. It also resulted in low overall thermal efficiency since a significant amount of heat was radiated directly from the emitter to the collector.

The present approach is to determine the feasibility and merits of thermionic converters that operate at much lower temperatures. This results in a drastic reduction of internal heat radiation losses and allows the diode to be constructed of lower cost materials. According to some calculations, a conversion efficiency as high as 40% might be achieved if suitable emitter and collector work functions can be achieved. This compares with 10% to 15% efficiency that was obtained when the goal was to achieve high temperature operation.

Existing experimental facilities are already available and will be utilized to perform the experimental work required to define material properties and operating characteristics of the thermionic converters in the low-temperature operating regime.

(a) Low-Temperature Thermionic Converter R&T - The objective of this effort is to develop a low temperature thermionic converter.

The program will examine both the theoretical and experimental aspects of the subject. Plasma theoretical studies and measurements will consider the effects of low temperatures and low work functions on plasma losses. Surface theory work will apply the present understanding of low work function surfaces to the further development of thermionic converters.

The objective is to improve the performance of thermionic converters, namely their output voltage, the efficiency at low temperatures and large interelectrode spacings.

The approach will focus on reduction of such parameters as collector work function, collector double sheath and the plasma drop. Developments in metal-oxide and semi-conductor surfaces suggest that low work function surfaces may be possible. In addition, preliminary analyses suggest that operation of the collector at low temperature would reduce the value of the double sheath. A reduction of plasma drop may also be achieved by plasma techniques.

(b) Thermionic Systems Technology - The long term objectives of this part of the program are to (a) define the system applications of low temperature thermionic power conversion systems used with nuclear, solar, fossil, hydrogen energy sources, etc., and (b) assist in the demonstration of the technology readiness of thermionic power systems which are cost competitive, efficient and reliable.

The approach used will entail the following studies:

1. Technology Base Evaluation:
   A compilation will be made of the existing technology base for thermionic systems work. Interfaces will be established with NASA Centers and other organizations active in the thermionic power field.

2. Applications Studies:
   The potential feasibility of thermionic power conversion with different heat sources will be evaluated for various applications such as building heating and cooling, process heating and cooling, auxiliary and emergency power plants, automotive power, space vehicle power, mining and tunneling and underseas power. Also the use of

thermionic converters in central station powerplant topping cycles will be studied.

3. Nuclear Reactor Studies:
   Coordination of system analyses with reactor systems studies at Los Alamos Scientific Laboratory will be provided in the definition of a heat-pipe-cooled reactor heat source for a thermionic power conversion system.

4. System Design Studies
   System conceptual designs will be generated based on the characteristics and operating regimes defined by the above studies.

NEED AND RELEVANCY:

The major significance of this research and technology effort is its potential to provide an energy conversion device which when operated in the low-temperature regime shows promise of a wide range of applications. In a topping cycle for conventional fossil fueled steam power plants, it is possible thermionic converters could increase efficiency of such plants from 35-40% to 50-60% overall. Furthermore, the cost per installed electrical kilowatt of the thermionic converters may be in the same range as that for the conventional power plant. Also, low temperature thermionic diodes can be heated with parabolic solar-energy collectors. This may be a more economical approach than large solar cell arrays for utilizing solar energy to generate electrical power for terrestrial or space applications.

Results of this thermionic converter research and technology program are expected to contribute to a definitive understanding of the capabilities of this device and potential areas of use.

Major Milestones of the Thermionic Converter Research and Technology program are shown with the list of Targets.

RESOURCES:

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	0	5	6	8	8	8
FUNDING REQUIREMENTS (K Dollars)	0	575	675	1000	1000	1000

OBJECTIVE: THERMIONIC CONVERTER R&T

(506-24-02)

HQ, LeRC, JPL

RESOURCES

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
LeRC	0	2	2	4	4	4
JPL	0	1	1	1	1	1
FUNDING REQUIREMENTS (K Dollars)						
Net R&D (NOA)						
HQ	0	250	300	300	300	300
LeRC	0	75	75	100	100	100
JPL	0	75	100	200	200	200
Total	0	400	475	600	600	600

OBJECTIVE: THERMIONIC SYSTEMS TECHNOLOGY

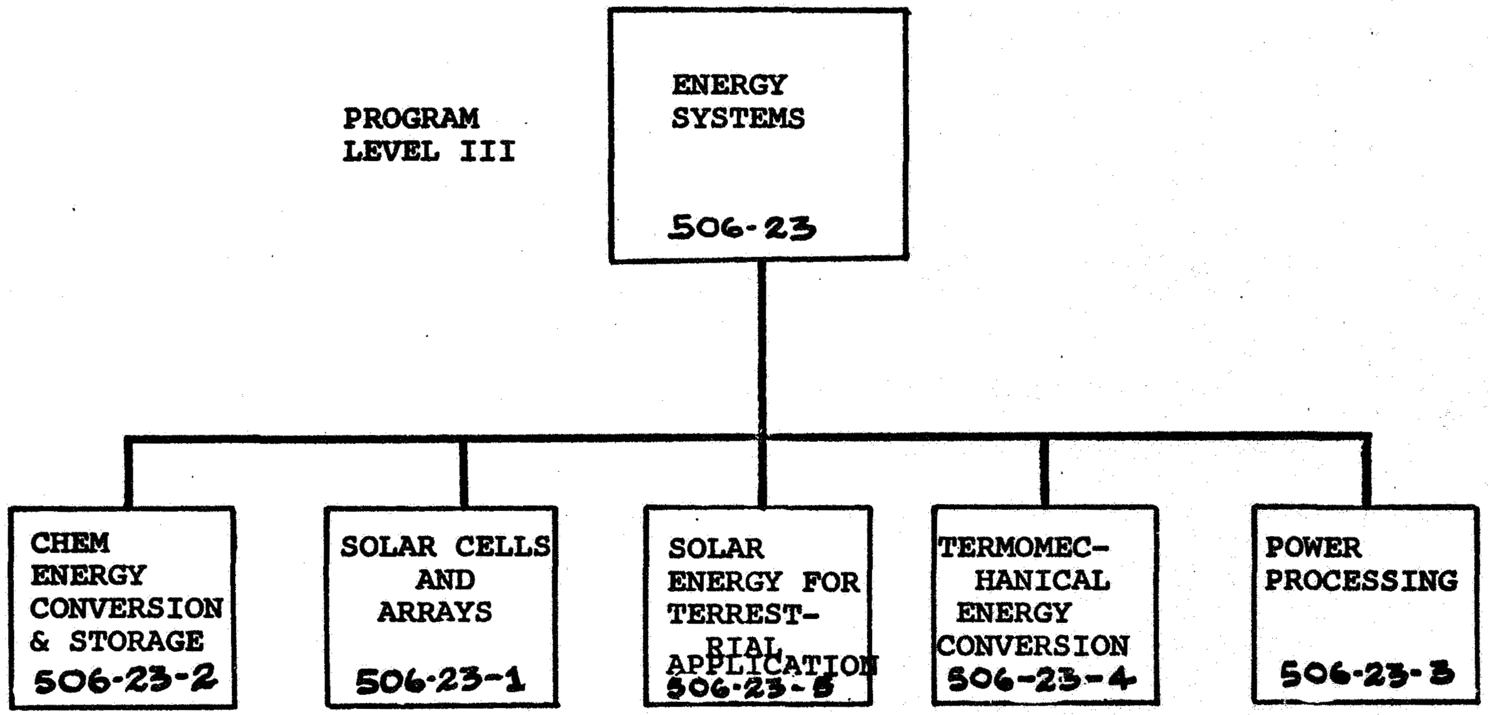
(506-24-03)

JPL

RESOURCES

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)	0	3	4	4	4	4
FUNDING REQUIREMENTS (K Dollars)						
Net R&D (NOA)	0	175	200	400	400	400

ENERGY SYSTEMS WORK BREAKDOWN STRUCTURE LEVEL III & IV



LEVEL IV SPECIFIC OBJECTIVES

ENERGY SYSTEMS

Program Objective

Provide, through technologic advances, standardization, and rationalized operating procedures, low cost, compactness long-life, and high reliability for power systems. The aims are:

- o Up to 90% cost reduction for solar cells and arrays
- o Doubling of life and energy density for electrochemical cells and batteries
- o Ten-fold increase in power capacity and doubling of life for power processing parts and circuits
- o Cost reduction by 75 percent for isotope power systems and more efficient thermomechanical engines for nuclear power
- o Economically competitive terrestrial systems, using unconventional energy sources, e.g., wind and photosynthesis.

Cost, bulk, weight, life, and reliability of power systems are key factors for routine and economic space systems, space exploration, and practical applications ranging from heart pacers to utility power stations.

The program is carried out primarily at the Lewis Research Center and the Jet Propulsion Laboratory, with smaller efforts at the Goddard and Marshall Centers.

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D						
IMS						
TOTAL R&D						
R&PM Resources						
TOTAL VALUE						
EST. NET COSTS						

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Chemical Energy Conversion and Storage

TYPE OF OBJECTIVE: X DISCIPLINE __ STUDY __ SYSTEM AND EXPERIMENTAL PROG.

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: Ernst M. Cohn

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To attain long life, high energy densities, and high reliability of electrochemical energy storage and conversion devices. This requires advances in component technology, in operating techniques, and in test and evaluation procedures.

Targets:

- o Determine the effects of zero-G on high power output (limiting current density) of Ni-Cd and Ag-Zn cells in FY 74.
- o Achieve a doubling of the life of Ni-Cd batteries (10-year target with 6,000 cycles/ yr. versus current 5-year capability) by means of non-gassing construction (FY 75) and screening through non-destructive testing (FY 76).
- o Triple energy density of batteries for 5-year use in synchronous orbit (400 cycles/yr., from 8-10 w-hr/lb to 20-30 w-hr/lb) by use of Ag-Zn batteries with new, inorganic separators by FY 78.
- o Screen candidate solid ionic electrolytes to select those that offer potential for operation below 100°C with alkali metal or alkaline earth anodes, for very high energy density (150 w-hr/lb) and indefinite shelf and cycle life.

APPROACH:

Research and development of chemical energy conversion and storage in NASA is conducted primarily at LeRC, JPL, and GSFC. Near-term emphasis is on a simultaneous approach to increased energy density, longevity, uniformity and reliability of electrochemical cells, resulting in lower costs of acceptance, test, and evaluation. A new anode structure will result in better charge control and makes possible negative-limited cells. As a result of the virtual absence of gas, a wetter cell becomes possible and cheaper, more durable plastic seals can be substituted for ceramic seals. Harmful overcharge is eliminated. Deeper discharge not only improves energy density but actually prolongs life in the case of Ni-Cd cells. A non-destructive, accelerated cell test is being developed. An inorganic separator, now permitting more than double the life of Ag-Zn cells (for synchronous orbit) may also find use in low-orbit cells.

Long-range, we have set ourselves the task of searching for a low-temperature, solid ionic conductor that permits fast transport of alkali or alkaline earth ions. If that search succeeds, the pay-off should be an indefinite stand life and cycle life, with a ten-fold increase in energy density, yet with no penalty in discharge rate.

Major milestones of the Chemical Energy Conversion Storage effort are:

- o Double life of Ni-Cd batteries (10 years, 6,000 cycles/yr.) by non-gassing construction (FY 75) and screening through non-destructive testing (FY 76).
- o Triple energy density of batteries for 5-year use in synchronous orbit (400 cycles/yr., 20-30 w-hr/lb) through Ag-Zn batteries with new, inorganic separators by FY 78.
- o Search for solid ionic electrolytes to operate below 100°C for 150 w-hr/lb cells with indefinite shelf and cycle life.

NEED AND RELEVANCY:

Energy storage aboard a spacecraft is needed for those times when some other primary power source (solar or nuclear) is not functioning, e.g., on take-off, during maneuvering, while in eclipse; for peak power demands; for emergency;

and, of course, for the relatively short missions (Mercury, Gemini, Apollo) where such stored energy represents the only available energy source. Batteries were taken over from ground applications with few modifications. Years of testing and experience have taught us that neither the construction nor the mode of usage should remain unchanged. We are continuing to evolve higher quality products, having started with small cells that lasted for weeks and presently flying large batteries for up to five years. In turn, our experience is being reflected in improved consumer products that accept fast charges, can be both stored and used longer, and are safer and more reliable. Recently, e.g., a battery-powered, rechargeable pacemaker has been introduced, based on space battery experience, that permits at least doubling of battery life (hence half the number of operations for removal and implantation) and quick recharging through the skin. Other portable and mobile electric equipment is benefiting as well.

Chemical Energy Conversion and Storage

RESOURCES:

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER:						
(Head Count)						
Manpower	40.1	40.1				
FUNDING REQUIREMENTS:						
(K Dollars)						
Net R&D	1815	1690				
IMS	791					
GROSS R&D	2606					
Net JPL/GSFC R&PM RESOURCES	1056					
TOTAL VALUE	3662					
EST. NET COSTING	1665					

Chemical Energy Conversion and Storage

		NEGOTIATED		BEST ESTIMATES			
		FY 74		FY 75		FY 76	
Number & Title	Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power
502-05-51 Electrochemical Research	LeRC	285	10				
592-25-53 Electrochemical Technology	LeRC	618	22				
	LeRC	-70					
502-05-55 Electrochemical Energy Storage Res.	JPL	100	1.2				
502-25-57 Deep Space Batteries	JPL	405	4.3				
502-25-58 Battery Qual. Control & Tests	GSFC	380	2.7				
502-05-61 Solar & Chemical Power	HQ	97	0				
TOTAL		1815	40.2	1690	40.2		

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Solar Cells and Arrays

TYPE OF OBJECTIVE: X DISCIPLINE __ STUDY __ SYSTEM AND EXPERIMENTAL PROG.

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: Ernst M. Cohn

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To reduce array costs by up to 90% (from \$400/w to \$40/w), improve power density (from 30 to 50 w/lb), and reduce dynamic interaction problems. To do so requires greater radiation resistance, a large increase in the efficiency of conversion (from solar radiation to electricity), and novel modular design and construction techniques.

Targets:

- o Space qualify "violet", 14%-efficient Comsat solar cell in FY 74.
- o Space qualify low-cost FEP Teflon covers for solar arrays in FY 74.
- o Fly new primary standards of solar cells on balloons, and distribute to users by FY 75 for calibration of equipment, cells, and arrays.
- o Achieve pilot production of thin (4-mil instead of 8-mil) solar cells for light-weight arrays by FY 76.
- o Make available the potentially low-cost, single-crystal silicon ribbon cell for test and evaluation by FY 76.
- o Make available light-weight (50 w/lb instead of present 30 w/lb) solar array technology in FY 77.
- o Demonstrate resistant (18% efficiency at end of life) 8-mil solar cells by FY 78.
- o Low-cost (\$40/w instead of \$400/w) array technology will be available by FY 78.

APPROACH:

Research and development of solar cells and arrays in NASA is conducted primarily at LeRC, JPL, and GSFC. Emphasis is placed on a combined approach for high quality and low cost for both cells and arrays. In the former case, the efficiency of cells is being improved by changing the cell structure and minimizing impurities and imperfections. At the same time, wrap-around contacts with p+ built-in fields and thin cells are being developed for higher efficiency, higher radiation resistance and quicker, cheaper module fabrication; the modules, being lighter weight, will also have higher power densities. Continuous ribbons will minimize waste of expensive material, yield a more uniform product, and cut expenses. Plastic covers for flexible modules that can be used for a variety of space and earth applications, all will optimize performance while minimizing cost.

Major milestones of the Solar Cells and Arrays effort are:

- At user's request, fly new primary solar cell standards on ballons and distribute by FY 75.
- Pilot production of 4-mil solar cells for lightweight arrays by FY 76.
- Low-cost, single-crystal silicon ribbon cell ready for evaluation by FY 76.

NEED AND RELEVANCY:

Power is an absolute necessity for the operation of any spacecraft. As mission times get longer, as deep-space probes move farther away, as more hostile conditions are faced by the craft, as distances from the sun change drastically when compared with past missions, as solar electric propulsion becomes a necessity for certain types of missions, improvements in the quality and reliability of solar arrays become imperative. At the same time, the high costs of procurement, quality control, qualification, etc., must be reduced. A byproduct of these developments will be a lowering of the cost of solar photovoltaic power that will make such devices more competitive on the ground. We already find them in remote weather stations, light buoys, beacons, and road telephones here and abroad. Other specialty uses are being uncovered, and the demand for lower-cost solar arrays is increasing.

Solar Cells and Arrays

		NEGOTIATED		BEST ESTIMATES			
		FY 74		FY 75		FY 76	
RTOP Number & Title	Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power
502-05-50 Solar Cell Basic Research	LeRC	130	8.0				
502-25-52 Solar Cell Tech.	LeRC	490	22				
502-04-54 Planetary Solar Power Research	JPL	90	1.1				
502-25-56 Planetary Solar Power Technology	JPL	394 (+381)*	10.6				
502-25-80 High Effic. Solar Cell D&E	GSFC	100	1.4				
TOTALS:		1204 (+381) 1585	43.1	1510	43.1		

*Note: FY 74 NOA reduced by $381K as part of Congressional actions to reduce space R&T budget. FY 73 NOA provided is same amount to maintain planned program level of effort.

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Solar Energy for Terrestrial Applications

TYPE OF OBJECTIVE: _X_ DISCIPLINE __ STUDY __ SYSTEM AND EXPERIMENTAL PROG.

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: Ernst M. Cohn

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To define and provide the technology for utilizing solar energy as a practical, clean and inexhaustible source of terrestrial power.

Targets:

- o Establish a five year plan in FY 74 for wind power generation research and technology in support of the National Science Foundation which will furnish approximately $300K to fund the LeRC program in FY 74.
- o Initiate testing of an intermediate (100 kw) size wind power generation system suitable for use as a practical source of power in favorable locations, e.g., Culebra Island, Puerto Rico by end of FY 75.
- o In FY 75, design and complete prototype tests of solar heating and cooling system components such as collectors, absorption coolers, thermal storage devices and model systems tests.
- o In FY 76 complete installation and prototype tests of a 15,000 square foot solar collector system operating in conjunction with the Langley SEB building.
- o Complete initial studies to define the research and technology requirements of large scale (10^5-10^6 KW) solar electric generation components and systems by FY 1975.

- o Make an initial assessment of the potential of agriculture as a source of organic material for fuel purposes and to initiate experimentation by FY 75.

- o Determine the factors controlling the cost of the conversion of organic material to clean gaseous and liquid fuels by FY 1975.

APPROACH:

Attempts at conversion of solar radiation to other forms of energy have been made since antiquity, and some success in both conversion and storage has resulted. That is particularly true with using relatively low temperatures for heating purposes, and such secondary solar sources as waterfalls for generating electricity and winds for both electricity and mechanical energy purposes. But even these applications had remained submarginal as long as cheap fossil fuels were abundant and the costs of health, safety, and pollution were not internalized. As these conditions are changing, the desire to find additional sources of economically competitive energy has become highly vocal. It is worthwhile, therefore, to use our space-derived knowledge, as well as available engineering talents generally, to re-examine all the possibilities for using solar radiation, directly and indirectly, as a source for other forms of energy. Included are photovoltaic and solar thermal generation of electricity, solar heating and cooling of buildings, storing solar energy in plant life by way of photosynthesis, and using winds and ocean thermal gradients for generating electricity.

Major milestones of the Solar Energy for Terrestrial Applications effort are:

- o Design 100-500 kw wind power generation system by FY 75.

- o Define R&T requirements of 10^5-10^6 kw solar electric generation components and systems by FY 1975.

- o Assess the potential of agricultural fuel and initiate experiments by FY 75.

- o Determine cost of converting organic matter to clean fluid fuels by FY 1975.

- Complete first-round testing of solar collectors in indoor simulator facility by FY 74.

- Complete outdoor comparative tests of solar collectors by FY 75.

- Complete initial solar building model dynamics tests by FY 75.

- Complete design of Langley Building solar energy system by FY 75, including selection of collectors to be installed for first-generation tests.

- Install and obtain operational data including collector efficiencies and building heating and cooling load fulfillment by the solar system of Langley SEB building by FY 76.

NEED AND RELEVANCY:

The NSF/NASA Solar Energy Panel, which published its report in December 1972, came up with the following conclusions: "Then (by the year 2020) solar energy could economically provide up to (1) 35% of the total building heating and cooling load; (2) 30% of the Nation's gaseous fuel; (3) 10% of the liquid fuel; and (4) 20% of the electric energy requirements."

Solar

RESOURCES:

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER:						
(Head Count)						
Manpower	43.1	43.1				
FUNDING REQUIREMENTS:						
(K Dollars)						
Net R&D	(1585)*	1510				
IMS	932					
GROSS R&D	2136					
Net JPL/GSFC R&PM RESOURCES	1027					
TOTAL VALUE	3163					
EST. NET COSTING	1387					

* Consists of $1204 K FY 74 NOA and $381K FY 73 funds.

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Thermomechanical Energy Conversion

TYPE OF OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEM AND EXP. PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: P. Rex Miller

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To provide the technology of advanced thermomechanical energy conversion systems which will lead to (1) reduced cost space nuclear power systems and (2) manned space vehicle power systems.

Targets:

- o Complete in FY 1975 performance tests of a proof-of-concept 400 HP O_2/H_2 reusable power unit for space shuttle applications.
- o Complete deliveries in FY 1976 of components for an experimental 500-2000 We, 25% efficient gas turbine conversion system.
- o Complete in FY 1975 preliminary integration studies to determine the suitability of thermomechanical energy conversion systems in outerplanetary spacecraft.
- o Complete 10,000 hours of non-nuclear test in FY 1979 of a 500-2000 We 25% efficient, experimental gas turbine conversion system which, when used with the AEC developed 2000°F MHW isotope heat source, can reduce space isotope power system costs from the present value of \$20,000/We to under \$5,000/We.

APPROACH:

Technology development of thermomechanical systems will be conducted with emphasis placed on the eventual testing of experimental components and proof-of-concept systems as required to obtain the needed data and knowledge. Supporting investigations will be conducted in such areas as rotating component aerodynamics, rotor bearings, rotor stability, heat exchangers, component fabrication techniques, and system control. Analytical studies of potential application impact on technology needs, and of promising system concepts will also be performed to provide development guidance. Testing will be accomplished at contractor and in-house facilities as appropriate.

- O_2/H_2 Shuttle APU: This development, undertaken at the request of OMSF, is aimed at establishing the technology for a power unit suitable for generating hydraulic power for the Shuttle Orbiter.

  The principal technical uncertainties of the O_2/H_2 APU are the achievable turn-down ratio of the combustor and fuel feed-turbine load control.

  An O_2/H_2 APU system concept has been defined by contract studies. Combustor tests have been completed which demonstrated the requisite turn-down ratio.

  The remaining activity is aimed at developing and demonstrating APU control by mid-CY 1974. To accomplish this, a complete APU using flight-type components is being designed and fabricated. It will include the propellant conditioning feed system, a combustor-turbine unit, all controls, hydraulic pump, and a simulated hydraulic load.

  Continued development of the H_2/O_2 APU in FY 75 is dependent upon OMSF interest.

- Isotope Gas Turbine System: A gas turbine system concept has been defined for use in the .5-2.0 KWe power range which reflects a high degree of simplification over earlier concepts and lower system parasitic losses needed to achieve high conversion efficiencies at low power. Simplification will lead to the kind of reliability which will be needed for long duration unmanned missions. The system will be compatible with the 2000°F isotope heat source for the MHW RTG program now under development by the AEC. This program, which is an integral part of the AEC's program to develop low cost space isotope systems will lead to a proof-of-concept system test. The AEC and the DOD are considering contributing funding to accelerate the target date of the proof-of-concept system test because of a potential earlier need for this technology. Design and fabrication of experimental system components will be accomplished on a schedule compatible with an accelerated test. Contracts for the compressor-alternator-turbine rotating unit and recuperator were let in FY 74 for deliveries by mid-FY 76.

Investigations will begin in FY 1975 of the 1600-1800°F components which will be needed to couple the 2000°F isotope heat source to the gas turbine components. This work will include materials development, thermal cycle integrity tests of the heat source heat exchanger and superinsulation developement. Delivery of the heat source assembly, less isotope, is scheduled for mid-FY 76 also.

The above component delivery schedules are based on 670K of requested overprogram costing authority in FY 1975.

Studies will be continued in FY 1975 to determine the requirements for integrating a isotope-gas turbine system in future outerplanetary missions.

NEED AND RELEVANCY:

Thermomechanical conversion is employed where high thermal-to-electrical conversion efficiencies and/or high power density (low weight per unit of power) is essential. This type of energy conversion is employed extensively terrestrially, and its eventual need in space as power levels grow is unquestioned.

A light-weight turbine powered APU is required on the Shuttle Orbiter to provide the high hydraulic power needs required by aerodynamic control surfaces. This need will be met by either hydrazine or O_2/H_2 APU. However, there are significant technical uncertainties with regard to the latter; and OAST, at the request of OMSF, has undertaken a technology program to resolve these uncertainties in order to assure its potential availability for the Shuttle program. The H_2/O_2 APU has the potential of reducing total shuttle APU system weight, thus increasing shuttle weight margins at launch.

Isotope power systems are a proven space flight power system, and its mission use power level has now grown to nearly half a kilowatt. Higher isotope system power levels will be needed for future outplanet missions and for special DOD telecommunication satellites. In all cases today, relatively low efficiency but highly reliable thermoelectrics have been the chosen conversion mode. Because of the very high cost of isotope fuel and the need to conserve the scare fuel, high efficiency conversion is required if isotopes are to be used for these higher power levels. Gas turbine conversion is a prime conversion candidate for .5-2.0 KWe isotope power systems because of its high efficiency, ready adaptability to zero-g, and the already extensive technology base. The higher efficiency of gas turbine conversion can potentially reduce the inventory of isotope fuel needed and cost per watt electrical by a factor of four by comparison to existing isotope systems.

RESOURCES

A. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	8	5	5	5	5	5
FUNDING REQUIREMENTS (K Dollars)						
Net R&D[1]	1400	1325	1325	700	700	700
IMS						
TOTAL R&D						
R&PM Resources						
TOTAL VALUE						
EST. NET COST	419					

[1]For isotope thermomechanical systems only.

RESOURCES (Cont.)

B. RTOP Resources

		NEGOTIATED FY 74	
RTOP Number & Title	Center	Net $ (k)	Man Power
502-25-90 Thermomechanical Energy Conversion	LeRC	1350	29
502-25-91 Thermomechanical Power Systems for Planetary Applications	JPL	50	2
502-35-60 Hydrogen-Oxygen Pwr. Sys.	LeRC	0	6

C. Crosswalk Resource

1. Q percent of all resources are of primary relevance to the vertical cut"Basic Research".

2. 100 percent of all resources are of primary relevance to the vertical cut "Routine and Economic Systems".

3. 80 percent of all resources are of primary relevance to the vertical cut "Exploration of Space".

4. 50 percent of all resources are of primary relevance to the vertical cut "Practical Applications".

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Power Processing

TYPE OF OBJECTIVE: _X_DISCIPLINE__STUDY__SYSTEM & EXP. PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: P. Rex Miller

STATEMENT OF OBJECTIVES AND TARGETS:

Objective: To advance the technology of electrical power conditioning, distribution, and management to (1) achieve multi-kilowatt, high voltage capability, (2) enable unattended operation of 10-12 years, (3) reduce cost through modularization and standardization, (4) provide new, improved component and circuit concepts, and (5) develop analytical tools to better enable the characterization of Power Electronic Processes. Improvements in efficiency, transient performance, reliability and weight are also part of these objectives.

Targets:

- o Demonstrate in FY 1975 on a laboratory scale the concept of using on-the-array regulation of kilovolt, high power solar power systems applicable to ion propulsion and communications satellites.
- o Demonstrate in FY 1975 a 50 KW, 2 micro-sec. gate assisted silicon control rectifier suitable for multi-kilowatt power processing.
- o Characterize in FY 1975 potential deleterious interactions associated with the use of kilovolt electrical subsystems in a space plasma environment.
- o Test in FY 1976 a modular DC-DC converter which by various circuit combinations can meet a wide range of power processing requirements.
- o Develop by FY 1976 standardized regulator designs for controlling voltages ranging up to 400 volts and a design for a cooperative redundant inverter.
- o Complete in FY 76 tests of an engineering model of an advanced, light weight power processor for a 8cm station keeping ion thruster suitable for use on SERT C.

- o Evaluate by FY 1977 an experimental breadboarded 100-300 volt DC distribution system.

- o Provide by FY 1978 a computerized analytical program enabling evaluation of power processing system design alternatives and prediction system steady state and dynamic behavior.

APPROACH:

The work under this program will be accomplished principally by in-house and contract analytical studies and experimental investigations of breadboarded circuits and equipments. In general, the program is directed toward simultaneously solving the pressing technology needs of near-term high power and high voltage applications, while continuing with a long term program toward achieving low cost and more effective power processing capabilities. An overriding emphasis is placed on the achievement of commonality of power processing design techniques and analytical tools, standardized circuitry, and modularization of circuitry which will result in flexibility to meet a wide range of future power processing needs.

Advancements in micro-electronics and power processing components, such as transistors, magnetic cores and capacitors, has progressed rapidly in recent years as a consequent of private sector developments. These advancements form a base for the planned advances in space power processing technology.

- o Space applications in some cases require unique advances in basic electronic components, such as silicon control rectifiers, and high voltage power transistors not likely to be forthcoming from the private sector. These will be developed by this program as needed.

- o Based on NASA and private sector provided component advances, NASA will devise and test new electronic circuit concepts which can lead to standardization and modularization of power processing equipments. This work is a key element in achieving higher power and voltage capabilities, higher performance and lower cost processing systems. A major thrust in this area of work is the continued development and demonstration of the NASA invented method of power conditioning control called ASDTIC, which has the potential for achieving simultaneously excellent regulator stability, improved output regulation, and control standardization.

- Technology investigations will also be directed toward developing new concepts which will simplify power processing systems with the attendant benefits of improved reliability and lower costs. Examples of this are the investigations of on-array regulation of high voltage solar arrays and increased use of micro-electronics.

- Improvements in unattended life are being sought by tests of representative state-of-the-art power conditioning equipment to determine life limiting factors, tests to better understand the characteristic limiting "stresses" of electronic components, and a new approach to power conditioning redundancy which is based on improved performance cooperative active redundancy rather than standby redundancy.

- The technology of analytical assessments and transient response predictions of overall power processing systems is in its infancy. The achievements of the program objectives require advancing this technology. This will be accomplished by industrial contracts supported by university supplied analytical assistance.

The major milestones of this program are included under the section on targets.

NEED AND RELEVANCY:

Power processing systems are a necessary part of all manned and unmanned spacecraft. In the first decade of space flight, each power processing system was individually fashioned from state-of-the-art technology of components and circuitry in accordance with project needs and was contunually being modified to incorporate expedient solutions to problems encountered.

This approach, while meeting specific project needs, has not advanced the fundamental understanding of power processing nor the overall technology base. The consequence of this was in some cases very high development costs, unexpected overruns, and delayed flight schedules. For example, the cost of the power processing system for some missions approached 45% of the non-recurring costs of the overall mission power system. The development of an improved analytical and experimental technology base is needed to correct these deficiencies.

In addition, the existing technology base is inadequate to meet the new power processing capabilities which near term missions and missions in the 1980's require. These missions include high power communication satellites, solar electric propulsion, outer planet spacecraft, large high power observatories, and manned missions to be built on shuttle capabilities. The new capabilities which will be required include high voltage power processing, longer operational lifetimes, improved reliability, on-board self diagnostics, and performance improvements needed to keep pace with performance advances in the power source.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER						
Manpower	35.7	35	35	35	35	35
FUNDING REQUIREMENTS (KDollars)						
Net R&D	1250	1175	1250	1350	1350	1350
IMS	350					
TOTAL R&D	1600					
R&PM Resources	858					
TOTAL VALUE	2458					
EST. NET COSTS	1139					

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	Man Power
502-25-70 Advanced Low Cost Power Proc. & Dist. Technology	LeRC	375	17
502-25-71 High Performance Power Electronic Components	LeRC	350	9
502-25-72 Pwr. Proc. for Earth Orbital Space Science & Applications Satellites	GSFC	70	.3
502-25-74 Long-Life, High Performance Power Proc. for Planetary Appl.	JPL	375	7.9
502-25-73 Multi-KW DC Dist. System Technology	MSFC	80	1.5

c. Crosswalk Resource:

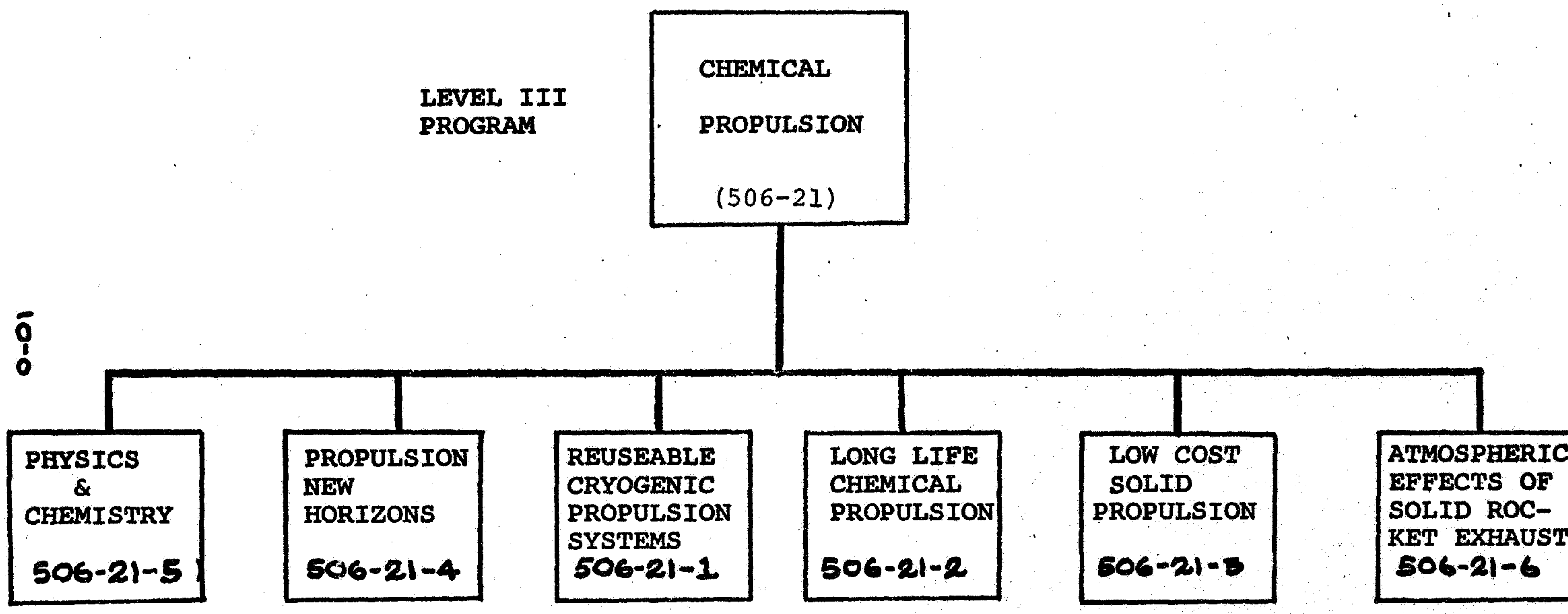
1. 10% of all resources are of primary relevance to the vertical cut "Basic Research"

2. 80% of all resources are of primary relevance to the vertical cut "Routine and Space Systems"

3. 70% of all resources are of primary relevance to the vertical cut "Exploration of Space"

4. 80% of all resources are of primary relevance to the vertical cut "Practical Applications"

CHEMICAL PROPULSION WORK BREAKDOWN STRUCTURE LEVELS III & IV



LEVEL IV SPECIFIC OBJECTIVES

10-0

March 1, 1974

CHEMICAL PROPULSION RESEARCH AND TECHNOLOGY

Program Objective

Provide the technology to meet the continuing need for cost reduction in propulsion, for high performance systems suitable for long duration planetary missions and for compliance with atmosphere pollution standards. The specific targets are:

- o Technology for high performance hydrogen-oxygen systems that can be reused at least 20 times, thus reducing cost.
- o Components for high energy systems that can endure 10 year missions.
- o Restartable and very high mass fraction solid propellant motors for cost reduction in applicable missions.
- o Knowledge of the size, concentration, and dispersion of aluminum oxide and hydrogen chloride from shuttle boost motors.
- o Basic research in the sciences and processes of chemical propulsion, to prevent and solve problems and to extend the boundaries of energy storage and use.

Chemical propulsion is used in almost all space missions. Its efficiency, energy level, smoothness, reliability and cost have major impact on the weight and velocity capability of launch vehicles and spacecraft, and hence on the data obtained in missions. This program provides needed data, buttresses weak areas of technology, solves problems, extends capability, and in general maintains the demonstrated NASA competence in chemical propulsion.

PROGRAM RESOURCES

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	261.0	254.0				

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D	6257	5900				
IMS	2105	1400				
TOTAL R&D	8362	7300				
R&PM Resources	6154	6154				
TOTAL VALUE	14516	13454				
EST. NET COSTS	6139	5800				

OBJECTIVE DOCUMENTATION

TITLE: Physics and Chemistry of Chemical Propulsion

TYPE OF OBJECTIVE: X DISCIPLINE __ STUDY __ SYSTEM AND EXPERIMENTAL PROG.

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: F. Stephenson

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To expand the basic understanding of injection, mixing, combustion, and other chemical and physical processes in liquid and solid rocket propulsion systems, in order to provide higher performing, more reliable, and lower cost systems for future missions.

Targets:

- o Establish techniques and provide data for design of stable, efficient, high performance rocket engines, by providing analytical models of the combustion and flow processes, and techniques to specify the influence of baffle and cavity variables on combustion. Consider gas-gas, gas-liquid and liquid-liquid mixing processes.

- o Measure and predict the thermodynamic, kinetic and transport properties of hydrogen, oxygen, fluorine and other propellants, at pressures up to 12,000 PSI, and over the temperature range of 25^{o}-360^{o}R, by 1975.

- o Determine the amount of back flow from rocket nozzles under space conditions, and the potential for damage to spacecraft surfaces, solar cells and optical elements, by 1976.

- o Develop and verify mathematical analysis for solid propellant grain stress analysis for non-isothermal conditions, by 1977.

- o Determine the governing parameters of the burning process of various materials under low or zero gravity conditions, and explore and define methods to quench fires in spacecraft under these conditions.

APPROACH:

Analytical and experimental tasks are carried out at JPL, LeRC, Universites and contractors, dealing with the basic sciences and technologies involved in chemical propulsion: combustion, fluid flow, heat transfer and thermodynamics. The philosophy is to maintain within NASA a competence to deal with the design and definition of future propulsion systems, and to discover and solve potential problems in existing systems.

- LeRC is continuing investigations to understand the influence of baffles, acoustic liners, injectors and nozzles on combustion stability and on the mechanisms that control the amplitude and shape of the combustion wave. The mixing processes in engines and explored and analysis is made of mixing by turbulence in the main section of the combustor and of recirculation near the injector face.

- JPL analyses and measures the efflux from the boundary layer regions of rocket nozzles in simulated space condition, and measures the density of the fluid in the flow field. The purpose is to detect the mass flux in the far field, corresponding to the probable location of spacecraft windows and other critical surfaces.

- The mixture ratio distribution for reacting spray formed with various fuels and fluorinated oxidizers will be determined by JPL for single injector elements. The boundary layre compositions will be measured and — related to the spray properties.

- Techniques for measuring the instability response function for solid propellant will be developed, so that motor stability boundaries can be calculated.

- JPL pursues analytical and experimental studies on polymer network formation and on compounds of interest to solid rockets. The influence of biaxially straining on polymers for propellants will be measured. Thermal conductivity measurements will be made on biaxially strained polymer sheets to determine the conductivity difference from the differing strains. Fractures studies will be carried out on gums and filled elastomers for solid propellants, and measurement made of life time in fatigue as a function of temperature and density.

- The boundary layer integral matrix procedures (Blimp) for predicting boundary layer losses in rocket engines will be modified as required by comparing predicted results with test data from real engines. The two dimensional kinetic computer program for predicting rocket performance will be modified to allow for the consideration of vaporization and for combustion in the region from the nozzle throat plane to the exit plane. Other programs for predicting performance will be modified to include three dimensional effects.

- Analytical and experimental studies for evaluation of hazards and to establish safety criteria are in process at LeRC.

Major milestones in this objective are as follows:

1975 - Measurement and computation of thermodynamic, kinetic, and transport properties of hydrogen and, oxygen to 12,000 PSI.

1976 - Determination of the back flow field from thruster nozzles.

1976 - Measurement of the burning rate of materials at low gravity, and definition of quench methods in low gravity.

1976 - Establishment of analytical models of combustion and flow processes to reveal the influence of baffles and cavities on combustion instabilities.

NEED AND RELEVANCY:

Efficient, stable propulsion systems are necessary for essentially all space missions. The deep understanding and capability generated through this research work will result in more efficient propulsion designs, yielding increase in mission capability and reliability; will provide a technology base and NASA inhouse competence to deal with unforseen problems exposed in developments and missions; and will disclose areas for developing new propulsion concepts leading to large increase in capability and effectivness.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	71.6	71.6				
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1128	1050				
IMS	744	744				
TOTAL R&D	1872	1794	1750	1800	1850	1900
R&PM Resources	1986	1986				
TOTAL VALUE	3858	3780				
EST. NET COST	1176	1123				

b. RTOP Resources

Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
502-04-20 Spacecraft Prop. Res.	JPL	238	6.7	200	6.7	200	6.7
502-04-45 Sol. Prop. Res.	JPL	200	4.5	200	4.5	200	4.5
502-04-21 Launch Vec. Tech.	MSFC	50	0.3	50	0.3	50	0.3
502-04-22 Performance Pred.	JSC	50	0.1	50	0.1	50	0.1
502-04-25 Liquid Rocket Res.	LeRC	290	37.0	250	36.0	250	36.0
502-24-34 Chem. Prop. Res.	HQ	200	0	200	0	200	0
502-24-39 Safety Res.	LeRC	100	23.0	100	23	100	23
TOTALS		1128	71.6	1050	71.6	1050	71.6

c. Crosswalk Resource

1. 100% of resources are of primary relevance to the OAST focus "High Energy Propulsion Technology"

2. 100% of resources are of primary relevance to the OAST focus "Lower Cost Performance - Effective Systems"

3. 70% of resources are of applicable relevance to the OAST focus "Basic Research"

OBJECTIVE DOCUMENTATION

TITLE: Propulsion New Horizons

TYPE OF OBJECTIVE: X DISCIPLINE __ STUDY __ SYSTEM AND EXPERIMENTAL PROG.

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: F. Stephenson

STATEMENT OF OBJECTIVES AND TARGETS:

Objective: To generate new propellants and propulsion concepts which have the potential for specific impulse of 1000 seconds or greater.

Targets:

- o Establish the feasibility of stabilizing for 12 months or longer activated states of elements, with energy potential of 50K cal/gram or more.
  - By 1975, determine if atomic hydrogen can be stabilized by strong magnetic fields (100K gauss).
  - By 1976 determine if metallic hydrogen produced by megabar pressure is metastable at normal pressure.
  - By 1977 determine if triplet state helium can be stabilized in solid state.
  - By 1977 determine the feasibility of energy storage in highly pressurized materials containing large amounts of hydrogen or deuterium.
- o Define and evaluate propulsion systems based on energy transmitted by laser beam from a remote source.
  - By 1975 evaluate designs for transferring laser energy to hydrogen working gas.

- By 1975 measure the losses in transmission of laser beams through earth atmosphere.
- By 1977 determine the economic and mission effectiveness of the concept of laser-energized propulsion.

o Evaluate propulsion systems which use the atmosphere or solid materials of planets as a propellant.

- By 1975 define conditions for stable combustion of metals in simulated planet atmospheres.
- By 1976 establish designs and measure the performance of thrusters capable of operation in dense planet atmospheres.

APPROACH:

o Studies are made to screen advanced concepts and determine those which warrent detailed analysis and experimental activities. At the LeRC, experimental work to make and stabilize atomic hydrogen by use of high magnetic fields (100 kilogauss) and extremely low temperatures (.1-1.0 degrees K) is in process. The absorption capacity of materials for atomic hydrogen will be studied as a function of temperature and pressure, and the affect of magnetic field on absorption determined. Various high pressure techniques will be investigated to determine their application to the production of metallic hydrogen. Theoretical and experimental work is carried out at JPL to determine the feasibility of energy storage in solid He and in materials which absorb hydrogen and deuterium.

o Mission analysis studies will be made to define potential application for thruster systems which obtained their energy for laser beams transmitted from a source which may be located on the earth. Energy absorption tests will be run with a hydrogen gas seeded with various materials to further absorption of energy from an entering laser beam. Measurements will be made of the transmission efficiency of laser beams through earth atmosphere.

- o Design studies will be made of concepts which use planetary atmosphere or planetary solid for propulsion. The combustion characteristics of simulated Venus atmosphere will be determined with possible solid and liquid fuels, such as aluminum or diborane. After the definition of potentially fruitful propulsion concepts of this type, experiments will be performed with planet-atmosphere-breathing combustion systems using such fuels.

- o Experiments will be to generate selected excited states of elements and to measure their life at very low temperatures, in the solid state or condensed on solid substrate. Energy storage capability of solid helium will be investigated with the aim of achieving long lifetime and high specific energies .

Major milestones in this objective are as follows:

1975 - Make atomic hydrogen and measure its life at temperatures below 1 degree K in presence of 100 kilogauss field.

1976 - Operate megabar press to make metallic hydrogen.

1977 - Determine feasibility of energy storage in solid helium.

1977 - Determine feasibility of energy storage in hydrogen-rich materials.

1977 - Determine the economic and engineering effectiveness of the concept of laser energized propulsion.

1976 - Establish designs and measure performance of thruster for operation dense planet atmospheres.

NEED AND RELEVANCY:

Propulsion has historically been one of the key pacing technologies in the advancement of space exploration. Current chemical propulsion systems and achieving close to the theoretical maximum performance; about 500 specific impulse. These systems, augmented by solar electric propulsion systems with high specific impulse but very low thrust, will probably be adequate for anticipated missions through the 1990', but more difficult missions within the solar system after that time, and the impetus to reduce trip time to the outer planets and to begin exploration beyond the solar system will call for more energetic propulsion systems. In addition, the establishment of entirely new concepts for storage and use of energy would result in large reduction in the size of propulsion elements for missions within the solar system. The fundamental nature of the analysis and experiment in this program may be expected to result in contributions to physic, chemistry and other sciences, extending beyond the realm of space programs.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	25.8	25.8	28	28	30	30
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	545	623				
IMS	367	367				
TOTAL R&D	912	990	1400	1500	1500	1550
R&PM Resources	727	727				
TOTAL VALUE	1639	1717				
EST. NET COST	447	500				

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
502-04-36 Propagation Studies	LRC	50	2.0	50	2.0	50	2.0
502-04-35 Atomic & Metallic Hydrogen	LeRC	175	17.8	213	17.8	333	18.0
502-04-38 New Horizons	JPL	240	4.0	260	4.0	350	5.0
502-04-25 Laser Powered Propulsions	LeRC	80	2.0	100	2.0	200	3.0
TOTALS		545	25.8	623	25.8	1033	25.8

c. Crosswalk Resource

1. 100% of resources are of primary relevance to the OAST focus "High Energy Propulsion Technology"

2. 100% of resources are of primary relevance to the OAST focus "Innovative Technology"

3. 100% of resources are of applicable relevance to the OAST focus "Basic Research"

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Reuseable Cryogenic Propulsion Systems

TYPE OF OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEM AND EXPERIMENTAL PROG

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: F. Stephenson

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To provide and demonstrate by end of FY 77 the critical component technology (main engine, propellant system, and auxiliary propulsion) of high performance (470 I_{sp}) oxygen-hydrogen propulsion systems suitable for use with 2nd generation, reuseable upper stage vehicles capable of performing at least 20 missions with minimum refurbishment.

Targets:

- o Complete design and a analysis studies in FY 75 to determine feasibility of greatly reducing inert stage weight by integrating on-board auxiliary systems, (e.g., auxiliary propulsion, tank pressurization and expulsion, main engine chilldown, and fuel cell propellant supply).
- o Demonstrate light weight, fully reuseable insulation and composite propellant feed lines capable of retaining cryogenic propellants while operating in a low gravity earth orbit environment for 7 days per mission (20 mission minimum) by FY 77.
- o Demonstrate auxiliary propulsion oxygen/hydrogen reuseable thrusters in the 30-100 pound thrust range capable of 1 million pulses with a specific impulse of at least 400 sec. by FY 77.
- o Demonstrate component technology of a 20,000 pound thrust oxygen/hydrogen engine having a 10 hour operating service life, a 300 start capability and a 470 sec. specific impulse, including: (1) high speed (up to 100,000 RPM)

turbopump bearings and seals for cryogenic service by FY 75; (2) small LO_2/LH_2 high pressure (up to 4300 psia) turbopumps with ~70% efficiency by FY 77; and (3) a regeneratively cooled thrust chamber capable of 1200 thermal cycles (start/stop) without fatigue failure by FY 78.

APPROACH:

The reusable cryogenic propulsion systems program objective is concerned with the technology required for future shuttle upper stage vehicles (space tug) that can be recovered and reused for at least 20 missions with minimum refurbishment between flights. The general approach adopted by the Lewis Research Center is to use propulsion system design and analysis studies in conjunction with vehicle studies to establish critical component performance and life requirements necessary to meet the 20 mission goal, and then to conduct component hardware design, fabrication and test programs to demonstrate technical solutions to advanced technology problems. A high performance, reusable space tug will probably not be required until the middle 1980's, with phase B studies initiated in calendar year 1977. The planned approach is geared to complete component technology demonstrations no later than mid-calendar year 1977 in order to provide technical input data to the phase B studies to aid in configuration selection.

There are three major propulsion subsystems that require technology advances to achieve the established reusability goals: the main engine, the cryogenic storage and propellant feed system, and the auxiliary propulsion system. The LeRC approach is to conduct technology tasks in each of the major subsystem areas that utilize in-house capabilities coupled with contracted efforts in the proper balance to take advantage of available talents and unique facilities so as to optimize results with minimum expenditure of funds. The principal planned technology task in each subsystem area are:

Main Engine - The main engine technology problems are the longest lead time tasks and thus will receive initial emphasis. The goals are to demonstrate a 10 hour engine operational service life, including 300 start-stop cycles, while achieving a high level of engine performance. High combustion pressures are desirable for maximizing engine performance within a given space envelope, but also tend to aggravate technology problems. A combustion pressure of 2000 psia has been selected as the maximum practical limit based on design and analysis studies, and solutions to technology problems at this pressure will encompass those encountered at any lower pressure levels that might be selected for the ultimate engine design. The key technology tasks in the main engine area are:

a). Turbomachinery (Principally contracted effort)

- Long life, high speed cryogenic bearings and seals.
- Small, high efficiency liquid oxygen and liquid hydrogen turbopumps.

These technologies will merge into a demonstration of 10 hour life, high performance, minimum maintenance turbopumps.

b). Main Combustion Chamber and Expansion Nozzle (Principally In-house)

- Combustion and heat transfer experimental studies.
- Chamber material low cycle thermal fatigue analysis and experimental studies.
- High expansion ratio nozzle analysis and experimental studies.

These technologies will lead to the design of a fully regeneratively cooled thrust chamber capable of maintaining structural integrity over 1200 thermal cycles (to ensure 300 start/stop operational life) and delivering 470 sec specific impulse. This fundamental work will be accomplished by LeRC in-house using their Rocket Engine Test Facility, first at 600 psia combustion pressures and then following a facility modification with FY 75 C of F funds, if approved, at 2000 psia. Based on this in-house effort, contract work will be awarded to design and fabricate a regeneratively cooled chamber for demonstration testing.

Cryogenic Storage and Propellant Feed System - Starting with the technology that has been developed for super-insulations and composite structures, in-house and contract work will be carried out in the areas of reusable multi-layer insulations and light weight composite feed lines with the goal of demonstrating minimum weight thermal control and propellant feed systems capable of retaining the cryogenic oxygen and hydrogen propellants seven days in earth orbit per mission, on each of the 20 missions. Experimental studies will be conducted, both in-house and under contract, to demonstrate low gravity fluid technology applicable to reuseable cryogenic upper stage earth orbit operations.

Auxiliary Propulsion Systems - The initial approach in the auxiliary area will be to investigate various ways of integrating auxiliary system functions in such a manner as to achieve significant weight reductions over that which would result from completely separate systems performing each function. One example under study would combine the auxiliary propulsion system with main propellant tank pressurization and main engine chilldown. These in-house studies will lead to the definition of component performance and operational requirements from which contract efforts to design, fabricate and test hardware for technology demonstrations will result.

NEED AND RELEVANCY:

The primary relevance of the Reuseable Cryogenic Propulsion Program Objective in the OAST Space Matrix is to the specific OAST focus of "shuttle exploitation technology" which is part of the OAST emphasis on "technology for low cost exploitation of space." This work is directly concerned with the NASA committment to provide the nation with low cost efficient space transportation in the 1980's. The present mode of delivering payloads to space via expendable launch vehicles causes prohibitive operational costs. The Space Shuttle earth to orbit transportation system with a planned 1980 IOC is the first step towards minimizing operational costs through vehicle reusability. In order to extend this cost benefit to the total space transportation system, future upper stage vehicles carrying payloads from the shuttle low earth orbit to geosynchronous orbit and beyond should also be reuseable.

Initially, it will be necessary to use low cost, low performance upper stages with the shuttle, but when practical, a low cost (reusable), high performance upper stage needs to be developed to inexpensively deliver many of the anticipated large payloads of the future to geosynchronous orbit and beyond. Upper stage reusability inherently places greater demands on the vehicle since, at the least, it must return itself to the shuttle in order to be returned to earth for refurbishment and reuse. This effectively doubles the Delta V requirements and greatly amplifies the benefits of high engine specific impulse and high stage mass fraction. This program objective is thus dedicated to demonstrating the technology of not only fully reusable upper stage propulsion systems, but also high performance, minimum weight systems through the use of the oxygen-hydrogen propellant combination and the advancement of weight reducing fabrication and system integration techniques.

RESOURCES

a. Budget Resources

	FY74	75	76	77	78	79
DIRECT MANPOWER						
(Head Count)						
Manpower	94	94				
FUNDING REQUIREMENTS						
NET R&D	1929	1900	3300	3500	1000	
IMS	875					
TOTAL R&D	2804					
R& PM Resources	3112					
TOTAL VALUE	5916					
EST. NET COSTS	1478					

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man Power
502-24-24 Adv. Rocket Components	LeRC	654	23
502-24-31 Adv. Rocket Systems	LeRC	1275	42
502-24-32 Cryogenic Storage and Transfer	LeRC	0	10
502-24-33 Auxiliary Systems	LeRC	0	19
TOTALS		1929	94

c. Crosswalk Resources

1. 100% of resources of primary relevance to specific OAST focus of "Shuttle Exploitation Technology."

2. 100% of resources of applicable relevancy to specific OAST focus of "Lower Cost Performance-effective Systems."

3. 75% of resources of applicable relevancy to specific OAST focus of "Shuttle Technology."

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Long Life Chemical Propulsion

TYPE OF OBJECTIVE: x DISCIPLINE ___ STUDY ___ SYSTEM & EXP. PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: F. Stephenson

Objective: To provide by the end of FY 80 the technology for advanced high performance (385 sec. I_{sp} goal) planetary spacecraft propulsion systems with a mission life of five to ten years.

Targets:

- o Identify mechanisms of aging and degradation of materials and propellants by FY 76.
- o Establish techniques for predicting long term material compatibility and component life from short duration tests by FY 77.
- o Select best propulsion system concept (e.g., regulated tank pressurization system vs. blowdown system; bipropellant engine vs. combination bipropellant/monopropellant engine) for maximum system performance and reliability by FY 75.
- o Demonstrate light weight, long duration (2000 sec.) 600 pound thrust engine with a minimum 375 sec. specific impulse (biprop. or dual mode) by FY 77.
- o Establish design criteria for propellant system components (bipropellant shut-off valves, isolation valves, pressure regulators, tanks, joints and connections) for 5 year life by FY 76.
- o Verify 5 year life of components with short duration test techniques by FY 78.
- o Demonstrate total propulsion system operation and performance with near flight weight components by FY 80.

APPROACH:

The long life chemical propulsion technology program is structured to demonstrate technology readiness through a combination of in-house and contracted efforts designed to evolve from fundamental research and technology through component design and experimental verification and finally, integrated system testing.

The work is centered in four major technology areas: (1) System studies to define the optimum configuration, system operation and component performance requirements; (2) materials compatability and component design criteria, and experimental verification for 5 to 10 year mission life; (3) thrust chamber assembly performance, compatability, and long burn duration; (4) system technology demonstration.

- o Propellant and materials compatibility tests continue, with specimens withdrawn from the storage facility regularly. Studies to determine the role of contamination in liquid fluorine will continue, as well as the evaluation and application of the life prediction methodology generated under earlier contracts.

- o Systems studies are in process to determine the optimum feed systems of the blowdown type and compare then to the pressure regulated type. The requirements for propulsion system assemblies will be evaluated, and the thermal and structural integration of advanced propulsion systems into spacecraft analyzed.

- o Long life feed system components will be designed and tested including a high precision pressure regulator, an isolation value, and propellant shutoff valves. Long duration fracture toughness testing of titanium alloy with flox and liquid fluorine will be done.

- o Design and test of an engine for high energy, long life propulsion systems will be pursued. The emphasis will be on a passively cooled design and on obtaining a minimum specific impulse of 375 sec. with the capability for long duration missions.

Major milestones in this objective are as follows:

1977 - Establish techniques for predicting long-term material compatibility from short duration tests.

1975 - Design, fabricate and test lightweight thrust chamber assembly.

1975 - Test injector with lightweight thruster assembly.

1976 - Establish design criteria for long life valves, regulators and other components.

NEED AND RELEVANCY:

The duration of missions to the outer planets will be up to 10 years. This requires extremely reliable, high performing and flexible propulsion system assemblies and components. The work in this objective will provide the critical technology for high energy, long life advanced spacecraft propulsion systems. It will be applicable also to shorter duration inner planet missions and to the placement of satellites in earth orbit. Payload increase up to 30% can be achieved through the use of high energy propellants in place of the earth storable propellants currently in use.

RESOURCES:

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER:						
(Head Count)						
Manpower	8.9	8.9	12.0	13.0	10.0	9.0
FUNDING REQUIREMENTS:						
(K Dollars)						
Net R&D	523	530	1500	2000	1000	500
IMS	-					
TOTAL R&D	523	530				
R&PM RESOURCES	-					

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
TOTAL VALUE	523					
EST. NET COSTS	550					

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man Power
502-24-26	JPL	523	8.9		
TOTALS		523	8.9	530	9.0

c. Crosswalk Resource

1. 100% of resources are of primary relevance to the OAST focus "Spacecraft and Entry Systems Technology".

2. 80% of resources are of applicable relevance to the OAST focus "High Energy Propulsion".

3. 80% of resources are of applicable relevance to the OAST focus "Innovative Technology".

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Low Cost Solid Propulsion

TYPE OF OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEM AND EXPERIMENTAL PROG

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: Robert A. Wasel

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To generate the needed advanced solid propulsion technology and to demonstrate its readiness for flight application for expanded NASA utilization of these inherently low cost systems in launch vehicle and planetary orbital and landing applications.

Targets:

- o Make a 2 burn test (start, quench, start, quench) of a 17,000 pound thrust motor suitable for potential launch vehicles or shuttle applications under simulated altitude conditions in FY 75.

- o Complete demonstration of a low thrust/weight (2:1 vs. 5-10:1 current capability) high mass fraction motor for use with fragile planetary orbiters S/C by firing under simulated altitude conditions in FY 74.

- o Sterilize a 600 lb solid fuel motor by exposing it to thermal cycles (260°F-70°F) required by planetary quarantine standards, and static test it by FY 1976 to determine if any degradation is incurred by sterilization, and to determine the launch/transit environmental effects.

- o Determine nature of solid motor exhaust products (HCl, Al_2O_3), and the reactions with the atmosphere and their implications at the launch site, in the troposphere and in the stratosphere (global) by FY 1976.

- Demonstrate by FY 1979, the feasibility of a very high stage mass fraction (0.92 vs 0.88 current) utilizing an advanced case construction concept in which the combustion chamber becomes the nozzle of the succeeding stage.

- Determine and develop the component and motor technologies required to support the Shuttle OOS and Tug.

- Demonstrate by FY 1977 higher Isp (303 vs 286) and mass fraction (0.94 vs 0.92) in spacecraft propulsion module motor for outer planet and other high energy missions.

APPROACH:

- Methods are sought to retard the critical reactions occuring between ammonium perchlorate and binder, in order to further the heat sterilizability of propellant. The chemical changes in binder-oxidizer formulations undergoing aging and long term creep are explored. A trend analysis will be made of the damage from radiation and high temperature aging, to provide a basis to extrapolate the effects to 10 to 12 year space missions.

- The efficiency of fiber optics for transmitting laser light for pyrotechnic ignition will be established.

- Tests will be made of a restartable solid motor and of a quench system based on a solid rather than liquid. Design and fabrication of a chamber made of high strength graphite composite material will be accomplished. The grain shape to meet the design of this concept will be established and materials for a prototype case and nozzle combination will be procured from vendors.

- Process development will be started on a method to prepare surface-modified aluminum for more efficient combustion at low chamber pressures.

- The shock wave reflections and interactions, and flow instabilities of the gas dynamics in high back-pressure propulsion systems based on explosive propellant will be analyzed.

- The plume dynamics of solid rockets will be examined experimentally and theoretically to determine the plume composition and structure, and to establish the spreading pattern of the gaseous and particulate exhaust product of the shuttle booster motors.

Major milestones of the solid propulsion program are as follows:

1977 - Complete first full scale thrust termination test using a pyrotechnique quency system.

1977 - Static test high performance propulsion module solid propellant motor.

1978 - Complete second full scale thrust termination test.

1976 - Sterilizable motor test firing.

1976 - Small motor test of surface modified aluminum propellant.

NEED AND RELEVANCY:

Solid propellant motors are characterized by their relative symplicity, reliability and low cost in development and procurement. They were selected for the boost stage of the shuttle because these characteristics resulted in projected cost savings of more than $500M. Future missions set requirements for new technology for these low cost propulsion elements; thus heat sterilization is needed for planetary landers. This requires the investigation of new propellant compositions and the characterization of the mechanical behavior of propellant designs under temperature extremes. Some solid propellant motors will be exposed to gamma and particle radiation fields from onboard RTG (radio isotope thermionic generators) and from radiation found in the planetary belts of Jupiter and Saturn. The ability of motors and pyrotechnics to survive such exposure must be ascertained. There is need to understand the source of pyrotechnic shock on spacecraft and to design and establish advanced release concepts which will reduce shock.

For unmanned missions to 40 AU or out-of-the ecliptic, a multistaged ultra high mass fraction system using unconventional solid motors (conesphere) can provide the required high velocity increment. For missions involving vertical motion in the planets with dense atmospheres such as Venus, or Jupiter, ordinary chemical propulsion systems become impracticable and the new concepts of explosive propulsion becomes very attractive.

The use of solid propellant space shuttle motors will produce questions about the effect of exhaust products on the atmosphere and the environment. Work must be done to ascertain the nature and reactivity of the aluminum oxide and the hydrogen chloride of the exhaust.

RESOURCES:

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER:						
(Head Count)						
Manpower	33.0	33.0	33.0	33.0	33.0	33.0
FUNDING REQUIREMENTS:						
(K Dollars)						
Net R&D	1096	1450				
IMS	119	119				
TOTAL R&D	1215	1569				
R&PM RESOURCES	329	329				
TOTAL VALUE	1544	1898				
EST. NET COSTS	1713	1713				

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
502-04-41 Solid Exhaust	LaRC	100	8.0	50	8.0	100	8.0
502-24-41 Pyrotechnics	LaRC	50	1.0	50	1.0	50	1.0
502-24-46 Solid Propulsion	JPL	946	24.0	1350	24.0	1400	24.0
TOTALS		1096	33.0	1450	33.0	1550	33.0

c. Crosswalk Resources

1. 100% of resources are of primary relevance to the OAST focus "Lower Cost Performance-Effective Systems"

2. 100% of resources are of applicable relevance to the OAST focus "Innovative Technology"

OBJECTIVE DOCUMENTATION

TITLE: Atmospheric Effects of Solid Rocket Exhaust

TYPE OF OBJECTIVE: X DISCIPLINE __ STUDY __ SYSTEM & EXP. PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: R. A. Wasel

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To provide the technology necessary to define solid rocket exhaust composition and to predict the reactions with the atmosphere, the concentrations of resulting species in the troposphere and the stratosphere and the long term effects thereof.

Targets:

- o Characterize the aluminum oxide produced-the particle size, surface reactivity and effect on atmospheric reactions (e.g. adsorbing HCL, seeding rain clouds) by 1976.
- o Determine the reactions of hydrogen chloride with water vapor, rain, and Al_2O_3 by 1975.
- o Develop an accurate computerized model for booster exhaust clouds by 1976 which will allow prediction of the cloud shape and location under the effects of wind, diffusion, and temperature so that exhaust concentrations can be predicted.
- o Determine photochemical effects (e.g. $HCl + light \rightarrow Cl_2 + H_2$), reaction rate coefficients of exhaust products with natural stratospheric species (e.g. $Cl_2 + O_3 \rightarrow O_2 + OCl$), to predict several-year-long term effects by 1976.
- o Develop remote and in-situ instrumentation by 1976 for measuring concentrations of exhaust materials (HCl, Al_2O_3) and perform checkout measurements at selected launches.

APPROACH:

- o Assessment of the probable composition of exhaust clouds will be made, followed by equilibrium and kinetic calculations to reveal potentially important reactions in the cloud. Some measurements will be made in simulated clouds, to define critical reaction sequence and rate constants.

- o Semiconductor laser diodes, gaseous HCl chemical lasers and magnetically tuneable lasers for remote detectors of rocket exhaust will be evaluated.

- o The reactions between the shuttle solid rocket exhaust and atmosphere constituents will be investigated, including the reaction rates of HCl and aluminum oxide with ozone. High altitude aircraft will be used to sample the chemical constituents in the exhaust plume of the shuttle rockets and in the perturbed atmosphere produced by the ascent of the shuttle.

- o A two dimension meridinial model which includes the chemistry of the exhaust products emitted during launch will be established in order to take account of the diffusion of contaminants and the effect on the ozone balance of the stratosphere.

- o The toxic effects of exhaust from the solid motors will be determined by exposure of ecco systems to the exhaust products. The environmental fate of all of the exhaust products and the effect on the environment will be determined.

Major milestones in this objective are as follows:

1975 - Develop experimental techniques to characterize remotely chemistry of exhaust clouds. Assess the amount of ground deposits from the cloud. Complete measurement of surface phase reactions. Measure $HCl-O_3$ reaction rates.

1975 - Perform aircraft flight experiments to sample the exhaust from shuttle launch motors. Establish two demensional model of upper atmosphere which includes the chemistry of exhaust products emitted during launch.

1976 - Complete environment assessment with two dimensional model of upper atmosphere which includes the chemistry of exhaust products emitted during launch.

1976 - Complete environment assessment with two dimensional model of rocket exhaust products and establish three dimensional model.

1976 - Determine toxic and ecological effect of hydrogen chloride gas on animal species.

1976 - Determine reaction rates of exhaust products with stratosphere components, especially ozone.

NEED AND RELEVANCY:

The solid booster and liquid propellant shuttle motors will leave hydrogen chloride, aluminum oxide, water, and other products in the troposphere and stratosphere during the course of the vehicle flight. In addition, the entry of the shuttle vehicles will result in the formation of oxides of nitrogen in the atmosphere.

It is necessary to determine the effect of these components on the atmosphere and troposphere, both on a short term basis relating to the location of the products shortly after launch, and on a long term basis in relation to the stability of the critical layers of the stratosphere.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower						
FUNDING REQUIRE-MENTS (K Dollers)						
Net R&D	1036	1430	1035	435	100	
IMS						
TOTAL R&D						
R&MP Resources						
TOTAL VALUE						
EST. NET COST	775					

b. RTOP Resources

		NEGOTIATED		BEST ESTIMATES			
		FY 74		FY 75		FY 76	
RTOP Number & Title	Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Powe
502-24-80	MSFC	110	3.0				
502-24-82	JSC	65	1.7				
502-24-83	JPL	214	4.5				
502-24-84	JPL	130	1.4				
502-24-85	ARC	27	4.5				
502-24-86	ARC	25	0.2				
502-24-87	ARC	70	1.0				
~~502-24-88~~	~~LRC~~	~~395~~	~~11.0~~				
TOTALS		1036	27.3	1430*		1035*	

c. Crosswalk Resources

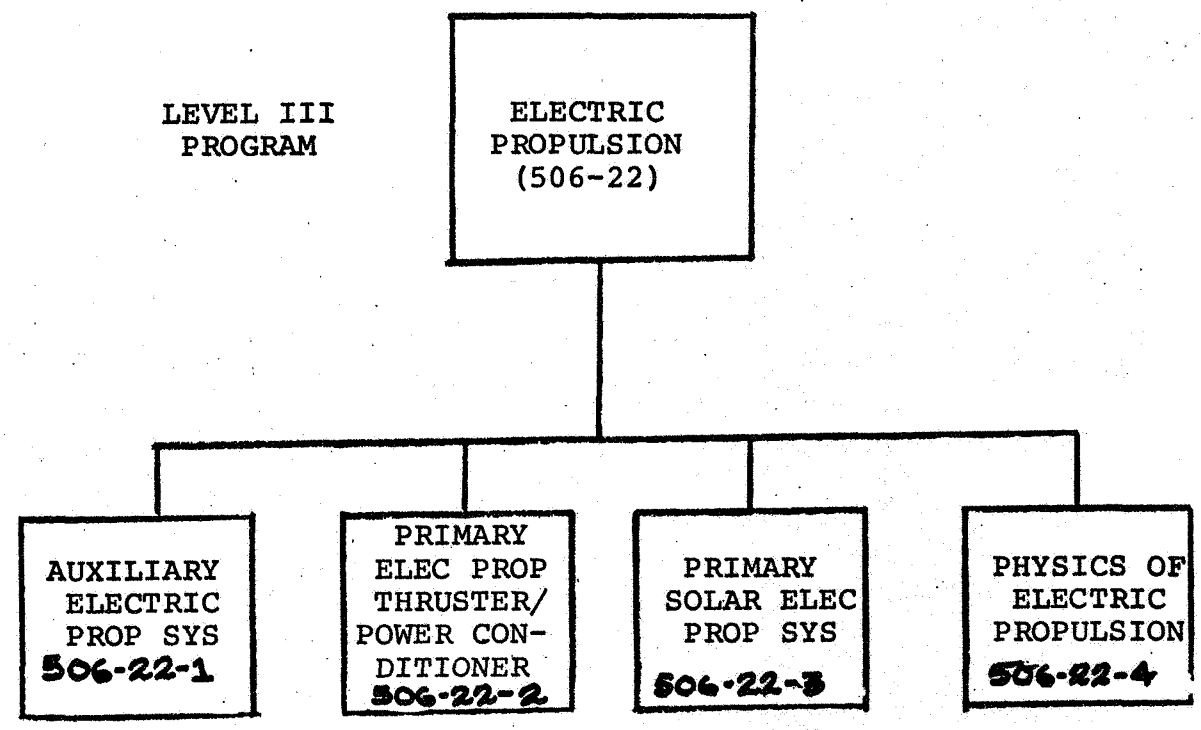
1. 100% of the resources are of primary relevance to the OAST focus "Shuttle Technology"

2. 100% of the resources are of applicable relevance to the OAST focus "Basic Research"

*Funding to be determined. OMSF organizing a Shuttle Program Office which will fund majority of the program, OAST will fund longer range, research-oriented portion. OAST funding estimated at $400K.

ELECTRIC PROPULSION WORK BREAKDOWN STRUCTURE LEVELS III & IV

LEVEL III
PROGRAM



LEVEL IV SPECIFIC OBJECTIVES

March 1, 1974

ELECTRIC PROPULSION RESEARCH AND TECHNOLOGY

Program Objective

Provide the technology for high specific impulse (greater than 1000 seconds) electric propulsion systems needed for advanced capabilities in near-earth and planetary/interplanetary applications. Specific areas of investigation include:

- Long life (greater than 5 years) auxiliary propulsion systems for station keeping and attitude control of application type satellites resulting in substantially reduced system weight and precise control capability.
- Technology for a 3 kW, 3000 second specific impulse ion thruster/power conditioner module suitable for integration into a 3-25 kW primary solar electric propulsion system.
- Demonstration and evaluation of system interactions of a 3000 second specific impulse integrated thrust subsystem capable of operating over a wide solar power profile range as would be encountered in planetary missions, and the technology for large (25 kW), light weight (15 kg/kW) solar arrays.
- Basic research in the basic processes to extend reliability and life, and to explore the full potential of electric propulsion.

High specific impulse propulsion offers payload and performance advantages which, for difficult missions, can be translated into cost advantages. Electric propulsion currently offers the only practical approach to specific impulses greater than about 1000 seconds.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Direct Manpower (Head Count)	97.7	96.0	84.0	80.0	73.0	60.0

Manpower

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D	3597*	3600	3650	3505	3000	2350
IMS	1320	1317	1290	1290	1290	1290
TOTAL R&D	4917	4917	4940	4795	4290	3640
R&PM Resources	2250	2283	1952	1952	1952	1952
TOTAL VALUE	7167	7200	6892	6747	6242	5592
EST. NET COSTS	3378	3600	3875	3420	2925	2225

*FY 74 NOA reduced by 303K as part of congressional actions to reduce space R&T budget. FY 73 NOA provided in the same amount to maintain planned program level of effort.

OBJECTIVE DOCUMENTATION

TITLE: Auxiliary Electric Propulsion Systems

TYPE OF OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEM & EXP. PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: James Lazar

STATEMENT OF OBJECTIVES AND TARGETS:

Objective: To demonstrate and establish the technology for long-life (approximately 5 years) station keeping and attitude control systems which will substantially reduce system weight for long-life (5 years) North-South station keeping as well as provide precise attitude control capability.

Targets:

- o Launch in FY 74, a 1 millipound, 150 watt ion thruster North-South station keeping flight experiment on ATS-F. Complete the operation and the evaluation of flight experiment by the end of FY 75. Complete ground test demonstration of 5 year cycle life capability (1800 cycles and 15,000 hrs. thrust time) by the end of FY 76.
- o Complete initial testing of an advanced integrated ion thruster/power conditioning system by the end of FY 76.
- o Complete evaluation of small (20 millipound) and large (5 lbs) resistojets using hydrazine and low freezing point monopropellants by end of FY 76.

APPROACH:

The major effort for this technology is concentrated at the GSFC and LeRC involving both ground tests and final verification of the technology in space. The programs at the GSFC are aimed at completion of the ATS-F ion engine (1mlb) flight test experiment to demonstrate North-South station keeping capability, and an evaluation of resistojets using hydrazine and low freezing point monopropellants to simplify on-board satellite propulsion systems. Emphasis at the LeRC is to improve ion thruster life and performance and to investigate new ideas and concepts.

- Although the ATS-F ion engine system will have a capability to station keep for almost two years, the spacecrafts' experiment schedule precludes operation of the ion thruster for this period of time. Therefore, a two year ground test, as indicated in the target, is to be carried out in conjunction with the flight to evaluate life capability of the system.

- The LeRC is to conduct investigations on an 8-cm ion thruster capable of operating over a wide range of thrust levels (1/2-2mlb), employing the same basic hardware. In addition, investigations aimed at improving life and performance through study of various thrust vectoring mechanisms, pyrolytic graphite discharge chamber components to reduce sputtering, high voltage pulse starting for reliability etc, will be continued. This effort will not only develop the technology for an advanced auxiliary propulsion system but will also act as a low cost test bed for these new approaches which will be applicable to the larger 30-cm thrusters for primary propulsion.

- Evaluation of the small resistojets (20 mlb.) operating on low freezing point monopropellants will be first completed to determine feasibility prior to scaling to the larger sizes (5 lbs.).

Major milestones are those as stated in the targets.

NEED AND RELEVANCY:

Auxiliary propulsion is required on virtually all spacecraft for such functions as maneuvering, station keeping, and attitude control. Because of its high specific impulse, small accurate impulse bit capability and repeatability, and its potential for long life, electric propulsion can provide a high degree of satellite control not possible with other propulsion systems, and in addition, can substantially reduce system weight and increase payload capability thus resulting in a more cost effective mission. For example, to accomplish 5 year North-South station keeping would require allocating 15 - 20% of the spacecraft weight for propellant using present chemical systems, whereas with electric propulsion, the propellant requirement would be only 2 - 3% of the spacecraft weight.

RESOURCES:

a. Budget Resources

DIRECT MANPOWER (Head Count)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Manpower	17.6	17.0	17.0	17.0	17.0	17.0

FUNDING REQUIREMENTS (K Dollars)						
Net R&D	845	590	590	590	590	590
IMS	258	258	258	258	258	258
TOTAL R&D	1103	848	848	848	848	848
R&PM Resources	529	529	529	529	529	529
TOTAL VALUE	1632	1377	1377	1377	1377	1377
EST. NET COSTS	878	615	615	615	615	615

b. RTOP Resources

		NEGOTIATED		BEST ESTIMATES			
		FY 74		FY 75		FY 76	
RTOP Number & Title	Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Powe
502-24-04 "Auxiliary Prop. Ion Thruster Tech"	LeRC	350	16	250	16	250	16
502-24-08 "Auxiliary Prop. Systems for Application Satellites"	GSFC	415	1	340	1	340	1
502-24-18 "Pulsed Plasma Thruster System Tech. Development"	JPL	80	0.6	0	0	0	0
TOTALS		845	17.6	590	17.	590	17

c. Crosswalk Resources

1. 100% of resources of primary relevance to the "specific OAST focus" of "Lower Cost and High Performanc Effective Systems"; and "High Energy Propulsion Technology."

2. Also applicable to "Civil System Technology," and "DOD Support."

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Primary Electric Propulsion Thruster/Power Conditioner Module

TYPE OF OBJECTIVE: X DISCIPLINE __ STUDY __ SYSTEM AND EXP. PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: James Lazar

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To provide and demonstrate by the end of FY 77 the technology for a 3 Kw, 3000 sec. Isp ion thruster/power conditioner module with a minimum life of 10,000 hours suitable for integration into a 3-25 kW primary solar electric propulsion system for future planetary and geocentric missions.

Targets:

- o Demonstrate ion thruster (30-CM diameter) full power (~2.75 kW) efficiency of 72% at 3000 sec. Isp and 64% efficiency at 1/2 power level by end of FY 74.
- o Demonstrate 10,000 hour ion thruster life and performance by mid FY 76
- o Demonstrate power conditioner efficiency of 91% at ~3 kW with a self radiating area of ~1 m^2 and a weight of 25 kg by mid FY 76.
- o Demonstrate thruster/power conditioner cluster compatibility (i.e., thermal and ion beam interaction effects) by end of FY 76.
- o Demonstrate 10,000 hour thruster/power conditioner module life and performance by end of FY 77.

APPROACH:

The OAST solar electric propulsion technology program consists of three major efforts: (a) an ion thruster and power conditioner effort at LeRC as outlined in this objective document, (b) evaluation of interactions of these components with other thrust subsystem and space vehicle components when operated as a complete thrust subsystem for mission use at JPL, and

(c) a large size, light-weight solar array (OAST/OSS jointly supported) effort at MSFC (see Objective titled, "Primary Solar Electric Propulsion System" for b & c).

The overall program will be based on a single set of technical requirements from the OSS supported MSFC stage and JPL propulsion module studies providing for a wide range of mission applicability beginning in the late 1970's or early 1980's. Monthly MICS reports will be issued by each Center covering their area of responsibility. In addition, quarterly meetings as a minimum will be held between the Centers and Headquarters to review progress, resources, and in general coordinate the total solar electric propulsion technology program.

Since the thrust subsystem integration and evaluation effort for mission use at JPL depends on delivery of thrusters and power conditioners from Lewis, it is of utmost importance that close liason between the two Centers and agreed to schedules be maintained. In addition, because the thruster and power conditioner are the two most critical items in the thrust subsystem that not only effect mission performance, but also space vehicle design, deviation from the established requirements should be agreed to by all those concerned.

Additional major milestones are:

End FY 74	Select power conditioner concept
End FY 74	Deliver two 30-cm thrusters to JPL
Early FY 75	Deliver third 30-cm thruster to JPL
Mid FY 76	Deliver two power conditioners to JPL

NEED AND RELEVANCY:

Electric propulsion has been shown to have considerable potential for satisfying the transportation requirements of future planetary and near-earth missions using either existing launch vehicles or the shuttle. To achieve full potential, the technology of the ion thruster and power conditioner must be advanced to meet the targets stated in this objective. In addition, this objective supports the final evaluation of these components when integrated into a complete thrust subsystem for mission use (See Objective titled, "Primary Solar Electric Propulsion System").

RESOURCES:

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER: (Head Count) Manpower	22	22	22	22	22	22
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1010	1450	1250	1250	1250	1250
IMS	577	577	577	577	577	577
TOTAL R&D	1587	2027	1827	1827	1827	1827
R&PM Resources	728	728	728	728	728	728
TOTAL VALUE	2315	2755	2555	2555	2555	2555
EST. NET COSTS	900	1235	1450	1200	1200	1200

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
502-24-03 Prime Propulsion Ion Thruster Technology	LeRC	1010	22	1450	22	1250	22
TOTALS		1010	22	1450	22	1250	22

c. Crosswalk Resources

1. 100% of resources of primary relevance to the "specific OAST focus" of "High Energy Propulsion Technology", "Lower Cost and High Performance Effective Systems," and "Shuttle Exploitation Technology"

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Primary Solar Electric Propulsion System

TYPE OF OBJECTIVE: X DISCIPLINE __ STUDY __ SYSTEM AND EXPERIMENTAL PROG

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: J. Lazar

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To provide and demonstrate by the end of FY 78 the technology for a 3000 sec. I_{sp} integrated modular thrust subsystem (thrusters, power conditioners, propellant system, switching matrix, thruster translator assembly, and computer control system) capable of operating over a wide solar power profile range such as would be encountered in planetary missions. In addition, the technology for large (25 kW) light weight (15 kg/kW) arrays will be demonstrated by the end of FY 76.

Targets:

- Select thrust subsystem design to meet a thrust subsystem weight of 12 kg/kW and an overall efficiency of 65% by end of FY 75.
- Demonstrate required operation of the following components: propellant subsystem, switching matrix, thruster gimbal assembly, and computer control matrix by end of FY 76. (Thruster and power conditioner components from another objective - "Primary Electric Propulsion Thruster/Power Conditioner Module").
- Demonstrate the structural and dynamic suitability of a light weight (15 kg/kW) solar array (one 12.5kW wing) by end of FY 76.
- Demonstrate performance and operation of the integrated modular thrust subsystem (using simulated solar array) and evaluate interactions between thrust subsystem components, and interactions between thrust subsystem and other space vehicle subsystems (i.e., EMI, computer noise sensitivity etc.) by end of FY 78.

APPROACH:

The OAST solar electric propulsion technology program consists of three major efforts: (a) an ion thruster and power conditioner effort at LeRC (See Objective titled, "Primary Electric Propulsion Thruster/Power Conditioner Module"), (b) evaluation of interactions of these components with other thrust subsystem and space vehicle components for mission use at JPL, and (c) a large size, light-weight solar array (OAST/OSS jointly supported) effort at MSFC. The JPL and MSFC activities are covered under this objective.

The overall program will be based on a single set of technical requirements from the OSS supported MSFC stage and JPL propulsion module studies providing for a wide range of mission applicability beginning in the late 1970's or early 1980's. Monthly MICS reports will be issued by each Center covering their area of responsibility. In addition, quarterly meetings, as a minimum, will be held between the Centers and Headquarters to review progress, resources and in general coordinate the total solar electric technology program.

- The MSFC/stage and JPL/propulsion module requirements will be integrated into a single set of technical requirements on which to base the thrust subsystem and solar array design and technology efforts.

- The JPL effort will demonstrate that the thrust subsystem will be compatible with the requirements of a projected mission. Key aspects will include (1) functional capabilities, (2) stability, precision, and accuracy of control of the thrust subsystem, (3) accurate characterization of the environment presented by the thrust subsystem, (4) definition of workable interfaces between the thrust subsystem and the key propulsion support subsystems, and (5) documentation of subsystem and component functional requirements.

- The MSFC solar array work will consist of analysis of existing technology and identification and solution of specific technology problems culminating in the demonstration and evaluation of a full scale wing to determine the adequacy of the design in both structural and dynamic characteristics. The wing will have a small number of active cell modules located in critical areas with weight and mass distribution simulation at other locations.

Major milestones are those as stated in the targets.

NEED AND RELEVANCY:

Electric propulsion with its high specific impulse and low development cost has been shown to have considerable potential for satisfying the transportation requirements of future planetary and near-earth missions using either existing launch vehicles or the shuttle. It currently is the only practical approach to specific impulses greater than about 1000 seconds.

The program is presently aimed at a technology readiness by the end of FY 1978 for mission use in the early 1980's. However, this timing does not meet OSS desires for a technology readiness date of FY 1976 which would provide OSS the option of carrying out a Comet Encke slow flyby mission with a launch in 1979 as a precursor for a follow-on Encke rendezvous mission in 1984 (launch 1981-82). Additional funds would be required in FY 74 and 75 to accelerate the technology readiness date from FY 1978 to FY 1976.

RESOURCES:

a. Budget Resources

DIRECT MANPOWER (Head Count)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Manpower	38.1	36.0	24.0	20.0	13.0	-

FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1391*	1150**	1400	1155	650	-
IMS	129	126	-	-	-	-
TOTAL R&D	1520	1276	1400	1155	650	
R&PM Resources	331	331	-	-	-	-
TOTAL VALUE	1851	1607	1400	1155	650	-
EST. NET COSTS	1290	1440**	1500	1195	700	-

*303K of FY 73 net R&D to be provided to JPL for use in FY 74 increasing the total net R&D to 1694K in FY 74.

**Funding level to depend on OSS/OAST FY 76 new start decision (OSS SEP Encke Slow Flyby mission or OAST SERT III)

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man Power	BEST ESTIMATES FY 76 Net $ (K)	BEST ESTIMATES FY 76 Man Power
502-24-11 and 502-24-11 SEP Thrust Sub-system and Systems Integration	JPL	987*	25.0	1095**	24.0	1400**	24.0
502-24-17 Solar Array Tech. for SEP Stage	MSFC	300	3.1	55	2.0	-	-
790-93-10 Adv. SERT S/C Technology	LeRC	104	10.0	** (TBD)	10.0	** (TBD)	-
TOTALS		1391	38.1	1150	36.0	1400	24.0

c. Crosswalk Resources

1. 100% of resources of primary relevance to the "specific OAST focus" of "High Energy Propulsion Technology", "Lower Cost and High Performance Effective Systems," and "Shuttle Exploitation Technology"

*303K of FY 73 net R&D to be used in FY 74 for a total net R&D = 1290K

**Funding level to depend on OSS/OAST FY 76 New Start decision (OSS SEP Encke Slow Flyby mission or OAST SERT III)

March 1, 1974

OBJECTIVE DOCUMENTATION

TITLE: Physics of Electric Propulsion

TYPE OF OBJECTIVE: X DISCIPLINE __ STUDY __ SYSTEM & EXP. PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Space Propulsion and Power Division: James Lazar

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To investigate and improve understanding of the controlling physical processes involved in electric thrusters and plasmadynamic lasers with a view toward improving the efficiency and lifetime of these devices.

Targets:

- o Investigate and determine governing parameters of the particle collision processes involved in erosion of cathodes and acceleration grids.
- o Investigate particle and plasma processes governing thruster efflux interaction with the spacecraft and determine governing parameters.
- o Determine plasma processes limiting efficiency of electric thrusters and efficiency, power density and attainable wavelength regions of plasmadynamic lasers.

APPROACH:

Research on the physics of electric propulsion is concentrated at the LeRC with one grant from HQ concerned, not only with electric propulsion but also with related areas such as plasmadynamic lasers. Emphasis is on investigating and determining the governing parameters which limit efficiency and life of these devices.

- o Ion thruster research at Lewis is aimed at conducting: ion thruster discharge chamber diagnostics via spectroscopic techniques and fundamental analytical studies, study of fluctuations in discharge plasma and beam-plasma interactions and their effect on thruster performance, preliminary investigations on thruster performance using Xenon propellant etc.

- A related area of plasma propulsion is the plasmadynamic laser. Emphasis here is to explore novel concepts and attempt to demonstrate their feasibility. Research will include estimating performance of laser concepts, methods to convert laser energy to alternative forms, and direct use of lasers.

NEED AND RELEVANCY:

The research program directly supports the technology effort in electric propulsion and provides for the continuing advancement that has been characteristic of this program over the past years to the point where it is approaching technology readiness. In addition, since it is a new emerging technology, the research effort continues to explore the full potential of electric propulsion and any related areas such as lasers.

RESOURCES

a. Budget Resources

DIRECT MANPOWER (Head Count)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Manpower	20	21	21	21	21	21

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D	351	410	410	410	410	410
IMS	356	356	455	455	455	455
TOTAL R&D	707	766	865	865	865	865
R&PM Resources	662	695	695	695	695	695
TOTAL VALUE	1369	1461	1560	1560	1560	1560
EST. NET COSTS	310	310	310	310	310	310

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
502-04-01 "Ion Thruster Research	LeRC	191	10	250	10	250	10
502-04-02 "Advanced Plasma-dynamic Laser Res"	LeRC	-	10	-	11	-	11
502-04-14 "Physical Processes in Elect. Prop. & PD Lasers"	HQ	160	-	160	-	160	-
TOTALS		351	20	410	21	410	21

c. Crosswalk Resources

1. 50% of resources of primary relevance to the "specific OAST focus" of "basic research," and 50% of primary relevance to "High Energy Propulsion Technology," and "Lower Cost and High Performance Effective Systems."

to provide the Ku Band design. Laboratory environmental testing will be conducted to determine the suitability for spaceborne applications.

- GSFC is also applying solid state techniques including combinations of Impatt diodes for high-power gain and Gunn Effect oscillators for frequency stability, to develop high-power transmitter modules operating in the frequency range above 7 GHZ. Breadboard models are being tested in the laboratory to gain insight into circuit techniques leading to the best methods of combining diodes which provide suitable output power while maintaining a highly efficient operating mode.

Major milestones of the Multimission Data Transfer and Tracking discipline are:

Early FY 75 - Complete laboratory evaluation of a spacecraft Ku Band paramp receiver.

Late FY 75 - Devise codes for communicating through the solar corona.

Late FY 76 - Fabricate and test a microminiature multimission spacecraft S-X band transponder.

Late FY 76 - Complete the design of a spacecraft solid state transmitter at Ku Band.

Late FY 76 - Select a more efficient code for outer planet missions.

Mid FY 77 - Demonstrate a 60 dB furlable conical antenna.

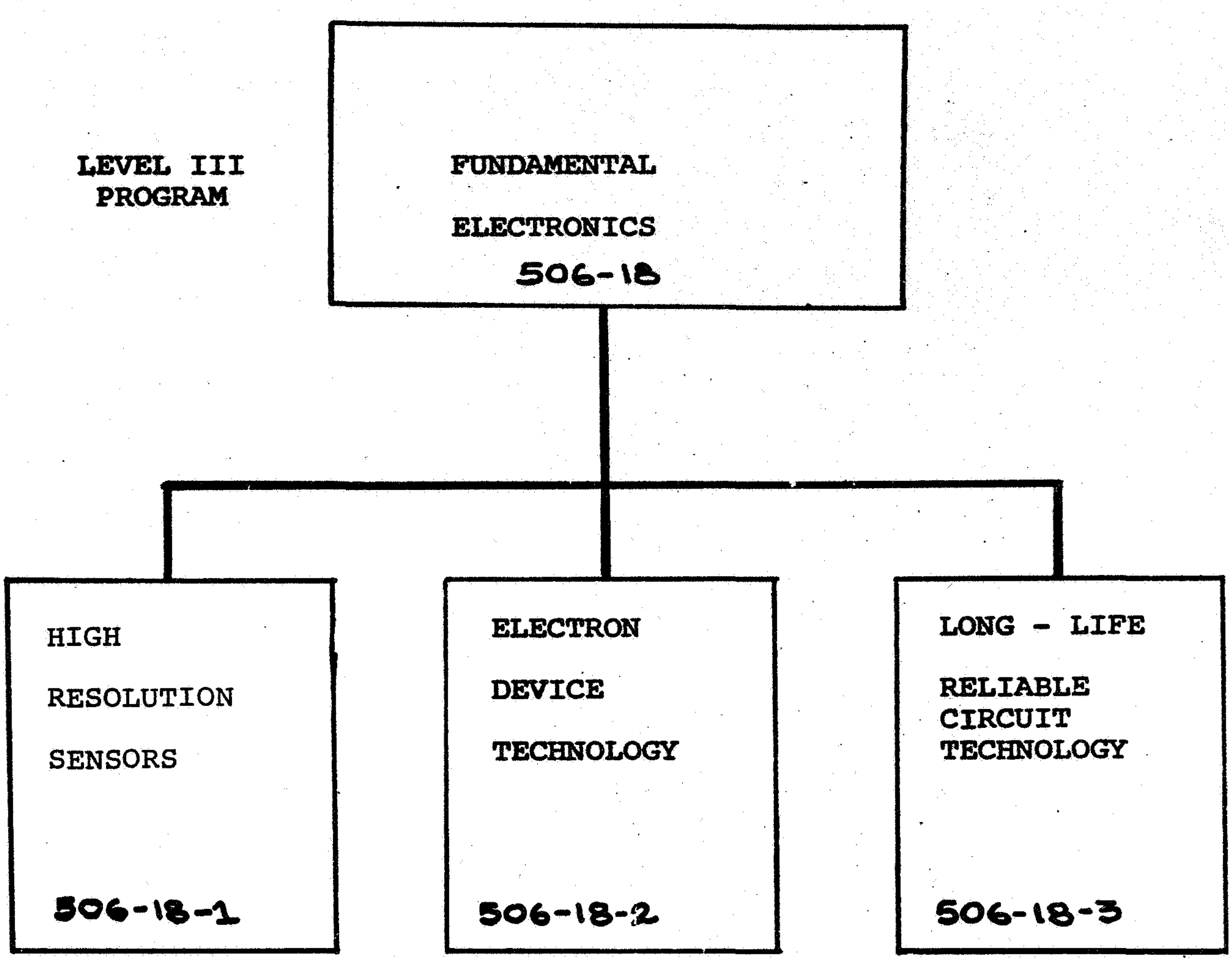
Late FY 77 - Complete design of multistage depressed collectors for X-band ECM tubes.

NEED AND RELEVANCY:

The value of any space mission is measured in terms of the amount of reliable information returned by the space to earth radio links. Thus the Multimission Data Transfer and Tracking program supports all NASA missions with primary relevance to "User Interactive Information Systems and Monitoring" and "Lower Cost and High Performance

FUNDAMENTAL ELECTRONICS WORK BREAKDOWN STRUCTURE

LEVEL III & IV



LEVEL IV SPECIFIC OBJECTIVES

FUNDAMENTAL ELECTRONICS

Program Objective

Provide, through theoretical studies and experimental investigations, the basic technology in advanced electro-optic concepts, electronic devices and long-life circuit arrays necessary for the design and synthesis of functional electronic systems. We will establish:

- Active and passive optical techniques for measuring pollution, earth resources, and planetary features.
- Electronic device concepts and components for the detection, measurement, storage and display of information which are smaller, lighter, more efficient and more economical than currently available technology.
- Methods for obtaining minimum failure rates and consistently high quality integrated circuit arrays with predictably reliable operating lives of 5-6 years.

Reserach and development of solid state semiconductor lasers and devices will lead to sensing systems for detecting and measuring environmental planetary and astronomical parameters. Studies and experiments on the physical properties of materials provide new ideas and techniques for performing electronic functions more effectively or at lower cost. Research on processing parameters, failure mechanisms and construction characteristics of integrated circuit devices provides standards and specifications needed to ensure acquisition of cost effective, reliable devices with operating lives suited to mission requirements.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	132	102	95	100	100	100

FUNDING REQUIREMENTS (K Dollars)	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Net R&D	4449*	3750	4315	4400	4550	4350
IMS	544	444	505	516	520	510
TOTAL R&D	4993	4194	4820	4916	5070	4860
R&PM Resources	4029	2992	2986	2963	2892	2892
TOTAL VALUE	9022	7186	7806	7879	7962	7752
ESTIMATED NET COSTS	3488	3580	4300	4400	4500	4400

*Does not include FY 73 NOA of $50K added to support the FY 74 program.

TITLE: High Resolution Sensors

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division - B. Rubin

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide sensors and sensing systems technology with the resolution, sensitivity, and reliability needed to enable man to acquire physical and scientific data effectively and economically under extreme operating conditions. Specific targets are:

- Establish, by FY 75, sensor systems which are capable of detecting incipient failures of structural members and rotating parts of space vehicles.

- Demonstrate, by FY 76, tunable lasers and detection systems which can detect atmospheric pollutants/constituents and particles less than one micrometer in diameter.

- Provide, by FY 77, a solid-state CCD imaging system with 10-100 times the sensitivity of the Mariner vidicon for outer planetary flybys.

- Demonstrate, by FY 77, an astronomical imaging system with sensitivity sufficient to detect 29th magnitude stars from an orbiting space telescope.

- Generate, by FY 77, airborne lidar systems for the rapid, remote detection of oceanographic features such as depth, turbidity, salinity and pollution with resolutions better than 1 meter at altitudes from 30 meters to 3 km.

APPROACH:

The High Resolution Sensor program in NASA is conducted at LaRC, WS, MSFC, GSFC, JSC and JPL. Emphasis is placed on the investigation of new technologies for improving the sensing and detection of information for NASA applications. Analytical studies and laboratory investigations of new materials, associated physical properties, and novel solid-state electronic phenomena will be conducted to provide improved sensors for aerospace mission requirements. Research contracts will be used to further develop these sensors for in-house laboratory application and evaluation. Ultimate testing of the sensors under flight conditions will be conducted to assure long-life reliability and stability.

- Planetary Imaging Sensors

  JPL is investigating solid-state imaging sensors to meet the anticipated requirements of planetary flyby, orbiting and probe missions. Current efforts are concentrated on the development of imagers based on charge-coupled device (CCD) technology. A two-phase contractual program with in-house evaluation of the resultant sensors is being used as the approach. The first phase is a study to evaluate the various configurations, functional characteristics, fabrication techniques, and performance parameters of the CCD sensors. The second phase will result in the development of a CCD imaging sensor for future Mariner and Pioneer Class Spacecraft. Associated optics and electronics will be developed concurrently with OA and OSS funding to result in a prototype-solid-state camera.

- Atmospheric Sensors

  A first generation high resolution tunable diode laser absorption instrument is being developed at LaRC and will be field tested to determine its operational characteristics as an airborne atmospheric pollution/constitutent monitor. The system contains tunable laser diode sources that cover the infrared range of from 4 to 10 micrometers. The system has been evaluated in-house with the gases sulfur dioxide and ammonia and excellent agreement between the experimental and theoretical absorption spectra has been obtained. In FY 74, a contract is planned to develop tunable laser diodes with power outputs $\geq$ 1 milliwatt in order to increase the sensitivity of the system. In FY 75, a further contractual effort will be made to improve the temperature operating characteristics and the stability of the system. Concurrently, in-house investigations will be made to simulate field tests. In FY 77, the system will be flight tested for the detection of NO_x, O_3, and CO.

o <u>Oceanographic Sensors</u>

Based on previous experience with LIDAR remote sensing to detect oceanic phytoplankton, a joint LaRC/WS team will conduct laboratory and field tests with available short pulse-width neon lasers and tunable dye lasers to establish feasibility and design parameters to measure ocean depth and turbidity. At the same time, the feasibility of using CW laser induced Raman backscattering to remotely detect the salinity of the oceans will be extended from the laboratory stage to the field. Both investigations are part of NASA's program to provide ground truth data to backup ERTS measurements of the oceans. LIDAR systems consist of a laser source, a telescope receiver, and a photo-detector and operate by transmitting a laser light pulse from a platform to and through some depth of water. The return signal is collected and detected. From the wave-length of the return signal, or from the time difference of the signals received from the ocean surface and bottom, salinity, depth, and turbidity are measured.

o <u>Astronomical Sensors</u>

GSFC has the responsibility to demonstrate high-resolution optical sensors for advanced astronomical space telescopes including the Large Space Telescope (LST). The approach is to utilize current and applicable electrooptic and electronic technology to attain an optical image of 10^7 to 10^8 picture elements of a star field, with a dynamic range of 10^6, for which the brightness of any element may be as faint as 10^{-2} photons/second. A special engineering test model of the astronomical sensor has been developed under contract and various alternative designs are being evaluated. This will result in the optimum combination of photoelectronic image conversion, electron-image gain, and electron-image readout to attain the desired resolution and sensitivity. The advisability of incorporating an all solid-state electron-image readout by means of CCD or CID techniques is to be assessed. The first prototype system will be used to evaluate the systems capability in the photon-counting mode, and demonstrate in practice its unique potential for detecting images of the faintest possible optical scenes from astronomical telescopes. Close coordination with the NASA Astronomy, Planetary, and Earth Resources programs will be maintained, the ultimate device being designed for use on the LST and other high quality optical imaging systems.

- <u>Spacecraft/Aircraft Safety Sensors</u>

  MSFC is investigating an acoustic emission technique for incipient failure detection on-board spacecraft and aircraft. Pulses of ultrasonic energy are emitted by every structural part under stress. This "fingerprint" is modified by changes in the physical characteristics of the material and these changes are manifested by changes in their ultrasonic energy spectrum. These changes are detected and are used as the basis for identifying potential failure. Prototype components for a failure detection system have been developed and preliminary tests will be undertaken. Final evaluation including identification of the failure mode will be completed in FY 75.

Major milestones of the High Resolution Sensors Research are:

Mid FY 75 - Complete test of incipient failure detection system for spacecraft.

- Complete platform tests of laser Raman scattering method for oceanic salinity measurements.

Late FY 75 - Complete CCD prototype sensor development for Planetary Imager.

- Complete laboratory measurements of gases SO_2, O_3, NO, and CO with tunable laser diode absorption system.

Mid FY 76 - Complete demonstration of Astronomical Photon-Counter TV System.

- Initiate flight tests of seawater turbidity measurements.

NEED AND RELEVANCY:

This program relates primarily to the sensing and detecting aspects of User Interactive Information Systems. Secondarily, it is relevant to Civil Systems Technology, Shuttle Technology, and Spacecraft Systems Technology.

For example, the need for observing remote planets such as Uranus with a surface brightness 1 order of magnitude less than Mars', will be met by the charge-coupled device imager. It will also reduce system costs by 50%, system complexity by a factor of 3 and power requirements by a factor of 4.

In earth environmental pollution monitoring, there is a need to replace the slow and expensive point-by-point collections of ocean water samples in bottles and their subsequent analysis in a laboratory with a more rapid, extensive and cheaper method. Remote airborne LIDAR techniques will reduce the cost per analysis by a factor of 20 and the time per analysis by a factor 120.

There is a requirement to maximize the reusability of future vehicles such as the Space Tug, the LST, Space Lab and Space Shuttle. To accomplish this, a method of detecting structural and engine incipient failure modes is required. This can be accomplished by the development and application of acoustic emission spectrum identification.

The High Resolution Sensors program will fulfill the needs of more sensitive, accurate, and reliable detectors where required by future NASA missions.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	37	20	19	25	25	25
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1437	1150	1250	1200	1200	1150
IMS	143	108	115	111	111	106
TOTAL R&D	1580	1258	1365	1311	1311	1256
R&PM Resources	1243	659	842	837	766	766
TOTAL VALUE	2823	1917	2207	2148	2077	2022

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man Power	BEST ESTIMATES FY 76 Net $ (K)	BEST ESTIMATES FY 76 Man Power
506-18-11 Advanced Imaging Systems Technology (502-33-94)	JPL	437	3	350	3	350	3
506-18-12 High Resolution Environmental Sensors (502-23-56)	LaRC	500	19	530	13	700	13
506-18-13 Astronomical Sensors (502-23-54)	GSFC	100	9	100	2	100	2
506-18-14 Sensor and Instrumentation Research (502-33-53)	MSFC	250	3	170	2	100	1
502-33-85 Space Shuttle Instrumentation/Sensors	JSC	150	3	0	0	0	0
TOTALS		1437	37	1150	20	1250	19

c. Crosswalk Resource

1. 100% of resources of primary relevance to the specific OAST focus of "User Interactive Information Systems and Monitoring."

2. About 33% of the resources are relevant to Spacecraft and Entry Systems Technology, 33% to Shuttle Technology and 33% to Civil Systems Technology.

TITLE: Electron Device Technology

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE___ STUDY___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division - B. Rubin

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide, through advanced synthesis, processing, and analytical techniques new or improved electronic materials whose properties are exploited for more effective and economical devices for the detection, storage, processing, and display of information. Specific targets are:

Displays

o In FY 75, demonstrate flat panel displays using:

Liquid crystals for high ambient light conditions, and
Light-emitting diodes (LED) for low ambient conditions.

o In FY 76, develop an engineering breadboard of limited scale to determine feasibility of a 3"X5", 64 lines/inch LED display, and a 4"X4", 30 lines/inch liquid crystal device for use as panel displays on board available aircraft.

Data Storage Devices

o In FY 75 - Investigate a linear charge coupled device (CCD) for high speed, high density imaging, data transfer and storage.

- Develop an organic isomer system as a data storage medium for a mass optical memory.

- Demonstrate bubble domain memory elements for an all solid-state storage device.

o In FY 76 - Breadboard and test a laboratory model of a 10^6 bit CCD buffer memory, with 10 μsec access time to a 32 bit word.

- Supply organic mass memory material to MSFC for evaluation in an optical memory system.

- Establish usefulness of a low-cost amorphous bubble domain memory material.

Electrooptical Devices

o In FY 75, establish feasibility of an IR CCD as a candidate all solid imager for earth observations.

o In FY 76, select optimum materials for an IR CCD device and fabricate a linear array.

APPROACH:

The electron device technology program in NASA is conducted at LaRC. Emphasis is placed on the investigation of new electronic materials, novel processing methods, and new or improved device characteristics such as longer life, smaller size, lower power consumption, lighter weight, higher sensitivity and precision for NASA applications. Materials include semiconductor compounds from groups II, III, IV, and V of the Periodic Table, garnets, metals, alloys, ceramics and organics. Processing techniques include ion implantation, cosputtering, liquid and vapor phase epitaxial deposition, radiation doping, and thermal diffusion.

Applications are related to information storage and display, photodetection, computer logic, photon conversion, imaging, and data handling for aircraft and spacecraft.

o The expertise and unique facilities of LaRC that have contributed to the solution of many of NASA's problems in electronics will be utilized to develop flat-panel type display devices for the limited space available in aircraft and spacecraft. Current efforts are concentrated on exploiting two new classes of materials; liquid crystals and semiconductor components from groups III and V of the

Periodic Table. Analytical studies and laboratory investigations of these materials and their properties have been and are used to develop these materials for device fabrication. The feasibility of a two-color (green/red) monolithic display which will be 3"X5" in size and have a resolution of 64 lines/inch is under investigation. Simultaneously, a medium sized (4"X4") liquid crystal display is being fabricated, with emphasis being placed on the optimization of a ferroelectric matrix addressing scheme. Final flight-testing of these devices will be carried out on LaRC aircraft.

- LaRC's experience in CCD development for shift registers, materials synthesis for semiconductor applications, and processing techniques in electronics, will be used to investigate new high density data storage devices. Three new approaches are being used:

  1) A novel organic molecular system that exists in two different spatial orientations. The conversion of one form into the other is caused by light and is the basis of writing binary information. The ease of conversion, the high storage density, and its low cost recommend it as the 10^{12} bit capacity storage material for the laser read-write optical mass memory.

  2) A thin film garnet material that generates magnetic bubble domains in the presence of a magnetic field. This is the basis for the solid-state data storage system that will operate with no moving parts.

  3) A linear array of metal-oxide-silicon "sandwich" units (a charge-coupled device) in which information can be stored as charge and transferred by rapid switching of the charge.

  The former two approaches are being done under contract with final evaluation in-house. The bubble domain memory will be used to store information at the 10^8 bit capacity level. The CCD will be applied as a buffer storage with the bubble domain memory. The organic system will be used as the archival mass memory with a 10^{12} bit capacity in the MSFC optical system.

Major milestones of the Electron Device Technology area are:

Mid FY 75 - Optimize IR CCD materials for uniformity and sensitivity.

Late FY 75 - Complete a 10^5 bit bubble-domain memory element.

Late FY 75 - Supply an organic isomer material to MSFC for evaluation in a prototype holographic optical memory.

Mid FY 76 - Evaluate and test a 10^6 bit CCD buffer memory.

Late FY 76 - Complete test of aircraft cockpit display devices.

NEED AND RELEVANCY:

The program's primary focus is on providing innovative technology for deep space exploration systems. At a secondary level, it is relevant to the data storage, display, and detection aspects of User Interactive Information Systems. As such, it relates to advanced spacecraft, the Space Shuttle, and military as well as civil aircraft.

For example, future avionic and space electronic systems will be digital and computer driven. There is a need then, to replace the CRT with a display device that will be compatible with these systems. This can be accomplished by light-emitting diodes or liquid crystal display arrays.

Furthermore, there is insufficient depth behind cockpit display panels to accommodate the CRT. The display must be reduced in thickness by a factor of 5. Both of these requirements can be met by light-emitting diode and liquid crystal display devices which will also provide an order of magnitude of improved reliability. Liquid crystals may provide a reduction in power consumption by at least an order of magnitude.

In the area of data storage, the replacement of the tape recorder with an all-solid-state no-moving-part system will require a buffer memory of 10^4 bits. Charge-coupled devices will thus fulfill this need.

There is a requirement to replace infrared data acquisition devices that are of the vacuum tube type with the more reliable, cheaper, and more accurate solid-state type. IR charge-coupled devices will fulfill these needs.

The Electron Device Technology program will provide improved performance information systems through new electronic materials and their properties.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	45.5	33.5	30.5	30	30	30
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1312*	1100	1265	1350	1400	1400
IMS	217	166	205	220	224	224
TOTAL R&D	1529	1266	1470	1570	1624	1624
R&PM Resources	1656	1219	1110	1092	1092	1092
TOTAL VALUE	3185	2485	2580	2662	2716	2716

* Does not include FY 73 NOA of 50K added to FY 74 program.

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man Power	BEST ESTIMATES FY 76 Net $ (K)	BEST ESTIMATES FY 76 Man Power
506-18-21 Electronic Devices and Components (502-03-51,52,53 502-33-51)	LaRC	1312	45	1050	33	1215	30
506-18-22 Electron Device and Systems Support (502-23-55)	HQ	0*	0.5	50	0.5	50	0.5
TOTALS		1312	45.5	1100	33.5	1265	30.5

* Does not include FY 73 NOA of 50K added to FY 74 program.

c. Crosswalk Resources

1. 100% of the resources of primary relevance to the "Specific OAST Focus" of Basic Research.

2. 50% of the resources are applicable to Innovative Technology.

TITLE: Long-Life Reliable Circuit Technology

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE___ STUDY___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division - B. Rubin

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: Provide integrated circuit technology and techniques to ensure that long-life, reliable large scale integrated circuit arrays and hybrid electronic devices can be produced economically and with consistent quality for all aerospace applications. Specific targets are:

- Establish hybrid circuit standards and production specifications by FY 1976 which can be used by all NASA programs to procure, test and qualify microelectronic devices with reliable operating lives.

- By FY 1977, determine design specifications, processes and test standards for a class of CMOS on insulating substrate circuit arrays to provide high speed, low power digital circuits for aerospace applications.

- By FY 1978, establish analytical models of device characteristics, failure mechanisms and construction to enable the prediction and attainment of specified reliable operating lives in CMOS on insulating substrate devices.

- By FY 1979, demonstrate complete automated facilities to evaluate and specify "hands-off" design, processing and testing of large scale integrated circuit arrays.

APPROACH:

Research on long life reliable circuit technology is performed in a coordinated, cooperative program at JPL and MSFC with supporting studies at other NASA Centers and major contractual support from the semiconductor industry. The program has two major thrusts - the development of new device and processing technology, principally at MSFC, and the derivation of techniques for predicting and assuring reliable operating-life components at both JPL and MSFC.

- MSFC engineers, working closely with their industrial counterparts, define design techniques, material characteristics and fabrication processes for each class of devices used in electronic systems. Current efforts are centered on Complementary Metal Oxide Semiconductor (CMOS) on insulating substrates as the next generation of technology expected to find major use in aerospace electronics. In a corollary study at GSFC, the various steps in device fabrication are being examined to determine the most economical point at which high reliability specifications required for space applications should be imposed.

- Complementing the device development activity at MSFC, a major emphasis is being placed on the investigation of automated techniques for the design, processing and test of integrated circuit arrays to minimize human errors, improve device reproducibility and reduce development time and cost. Unique computational facilities in the MSFC Astrionics Laboratory have been combined with pattern generating equipment to provide automation of the design and mask making steps of integrated circuit processes. Currently, automated photolithographic processes are being incorporated into the system. In subsequent years, techniques for automating the handling of wafers, the processing of devices and testing the finished product will be defined and demonstrated. When complete, the facility will provide a unique "hands-off" system for studying process-dependent reliability characteristics of devices and evaluating techniques for cost-effective and fault-free device production.

- At JPL, in-house experts in microchemistry and microphysics are examining integrated circuit construction processes to define failure mechanisms and develop mathematical models of these processes. These models will be combined with models of device characteristics and the operating environment to provide an analytical prediction of operating life. Concurrent with the modeling activities, new techniques for measuring device performance in the form of accelerated tests and analytical instrumentation are being studied to provide a methodology for evaluating the life prediction models. At MSFC, contractual studies are being pursued to establish device specifications and design rules for hybrid and monolithic integrated circuit arrays. Techniques for screening and qualifying parts to high reliability specifications are being developed. These techniques will be combined with the failure mechanics and modeling activity of JPL to provide standard long life components for future NASA missions.

In separate, but related efforts, both MSFC and JPL are examining current problems with TTL circuits commonly used in todays systems. Loose particles in the completed devices cause numerous failures in applications. MSFC is establishing techniques to passivate the surface of the devices and minimize the occurrence of the problem. At JPL, techniques for screening and detecting faulty devices during acceptance testing are being defined. These and other problems are pursued as part of this objective to ensure effective use of the expertise generated by the overall research program.

Major milestones in the Long Life Reliable Circuit Technology program are:

Mid FY 75	- Complete Preliminary CMOS Model
Late FY 75	- Verify CMOS Model
Late FY 75	- Complete Feasibility Demonstration of AVIS
Mid FY 76	- Complete Hybrid Circuit Standards
Mid FY 76	- Complete Accelerated Test Definition
Late FY 76	- Complete CMOS/SOS Process Evaluation

NEED AND RELEVANCY:

All aerospace missions rely on electronic and electromechanical systems for critical functional operations including the sensing, processing and transfer of information; the reception, interpretation and execution of commands; and the guidance, control and stabilization of vehicles. Because of the criticality of these systems to mission success, optimum performance and reliability are essential. In addition, longer missions such as those to the outer planets, satellites in synchronous orbits and transportation systems planned for repeated reuse require long operating lives ($>$5 years) to minimize logistics and system costs.

Long life reliable circuit technology will provide a base for the design of systems without resorting to redundancy and replication to meet reliability requirements. Standard specifications and components will provide 20-30% savings in the cost of acquiring and testing electronic components. New device technology will provide smaller (1 mil^2 vs 6 mil^2), cheaper ($10 vs $5) electronic devices with improved performance (10 ns vs 100 μsec access times) to meet future system requirements. This research directly supports the Lower Cost and Higher Performance Effective Systems focus and has important applications in User Interactive Information Systems and Spacecraft and Entry Systems for Deep Space Exploration. Because the technology involved is fundamental to all electronic systems, the work is also applicable to Civil Systems Technology, DOD support and Innovative Technology.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	49	48	45	45	45	45
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1700	1500	1800	1850	1950	1800
IMS	184	170	185	185	185	180
TOTAL R&D	1884	1670	1985	2035	2135	1980
R&PM Resources	1130	1114	1034	1034	1034	1034
TOTAL VALUE	3014	2784	3019	3069	3169	3014

b. RTOP Resources

		NEGOTIATED FY 74		BEST ESTIMATES FY 75		FY 76	
RTOP Number & Title	Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power
506-18-31 Design, Processing & Testing of LSI Arrays (502-23-51)	MSFC	550	25	490	24	650	20
506-18-32 Screening & Reliability Testing of Microcircuits & Electronic Devices (502-23-52)	MSFC	350	6	200	6	350	7
506-18-33 Predictable Long-Life Component Technology (502-23-53)	JPL	790	17	800	17	900	17
506-18-34 Highly Reliable Semiconductor Manufacturing Investigation (502-23-57)	GSFC	10	1	10	1	50	1
	TOTALS	1700	49	1500	48	1800	45

c. Crosswalk Resource

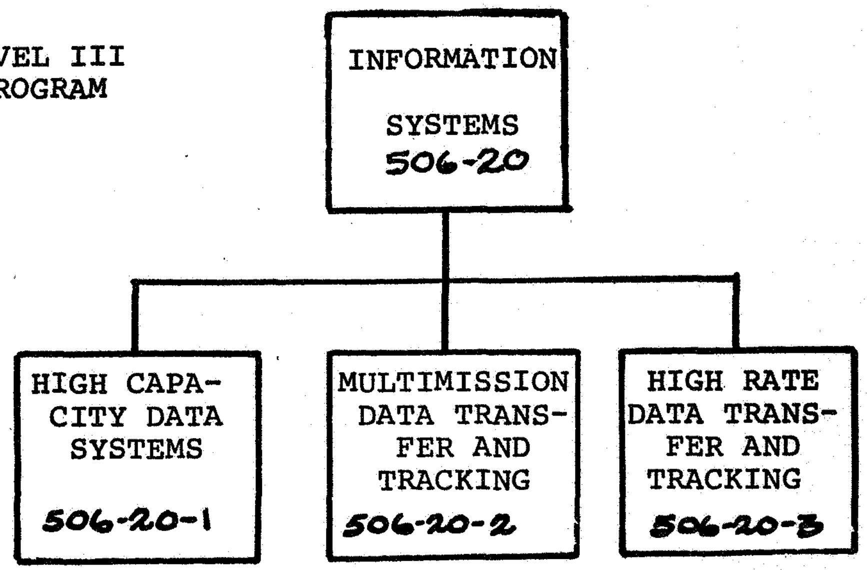
1. 100% of these resources are of primary relevance to the specific OAST focus on Lower Cost and Higher Performance Effective Systems.

2. 50% of the resources have applicable relevance to the OAST focus on User Interactive Information Systems.

3. 50% of the resources are applicable to the Spacecraft and Entry Systems Technology focus.

INFORMATION SYSTEMS WORK BREAKDOWN STRUCTURE LEVEL III & IV

LEVEL III
PROGRAM



LEVEL IV SPECIFIC OBJECTIVES

INFORMATION SYSTEMS

Program Objective

Provide, through research, design, and experimental tests the components and techniques needed for the processing, transmission, and reduction of data from planetary, applications, and data transfer satellites of the future. Our planned investigations will include:

- Techniques for higher speed of calculation, greater storage capacity, and longer life in spacecraft computer-based data processing systems.

- New designs for longer life, improved performance, S/C radio subsystems capable of multi-mission use so that planetary applications S/C can be built and tested at lower cost.

- Use of lasers to transmit and receive higher data rates for earth resources satellites, to determine satellite position for earth and ocean physics scientists, and to calibrate satellite sensors for earth resources sensors.

In the data processing program we will apply laser holographic techniques to the attainment of greater storage capacity and will use optical methods to increase the data processing rate. Longer life for deep space missions will also be attained by the use of innovative computer architectural schemes which provide redundancy and flexibility in the application of the major parts of the data processing system. Spacecraft radio subsystems for planetary missions will be made less expensive, more reliable and have higher performance. This will be accomplished by using integrated circuit and microminiature techniques in module designs which can be chosen to meet specific mission requirements. This approach will avoid the current expensive development of unique components for each mission application. It will also permit the later introduction of all digital modules as compatible units and thus attain reliability and stability inherent in digital circuits. Our laser data transfer program will concentrate on components such as lasers, modulators, pointing systems, detectors, space coolers and optical systems, and on laboratory tests of data transfer systems. Plans will also be made for a flight experiment program starting in 1976 to demonstrate the capability of transmitting data at a rate of 300 megabits per second between a spacecraft and earth.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER Head Count)						
Manpower	82.4	75.2	84.8	75	71.5	71
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	4265*	4600	5295	5720	5450	5200
IMS	540	440	530	540	515	490
TOTAL R&D	4805	5040	5825	6260	5965	5690
R&PM Resources	1682	1598	1675	1631	1593	1504
TOTAL VALUE	6487	6638	7500	7891	7558	7194
EST. NET COSTS	3926	4770	5200	5700	5600	5300

*Does not include FY 73 NOA of $355K added to support the FY 74 program.

TITLE: High Capacity Data Systems

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE ___ STUDY ___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division - C. Carl

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide design data and techniques which will permit construction of reliable, high speed, high capacity data processing systems for more effective and economical use in interactive information systems such as earth resource imaging and climatological modeling, in large time-shared data management systems, and in long-lived aerospace computer applications. Specific targets are:

- By FY 76, complete the conceptual design, breadboard fabrication, and laboratory test and evaluation of a modular, fault-tolerant data processor with operating life greater than 5 years for unmanned planetary spacecraft.
- Demonstrate laboratory feasibility of a three-unit multiprocessor data system to perform fault-tolerant data processing operations characteristic of manned spacecraft by FY 76.
- Design, assemble and evaluate, by FY 78, optical holographic memory systems having storage capacities of 10^{12} bits.
- By FY 79, complete breadboard construction of an optical computer and demonstrate feasibility of processing image data at 10^{12} bits per second.

APPROACH:

Work on High Capacity Data Systems is being carried out principally at the Jet Propulsion Laboratory (JPL), the Johnson Space Center (JSC), the Marshall Space Flight Center (MSFC) and the Goddard Space Flight Center (GSFC).

Each Center is emphasizing a different aspect of data systems and, at the same time, aiming to achieve the objectives of the High Capacity Data Systems.

- At JPL the work is aimed at achieving a standardized, low cost, long life, multimission data system for unmanned deep space explorations. Focusing on post 1978 deep space missions (i.e. Mariner Jupiter-Uranus, Mariner Jupiter orbiters, Mars and Venus follow-ons, etc.), hardware and software will be designed simultaneously, and a breadboard system will be constructed and tested in FY 76 to achieve an early technology readiness date. A low cost system design will be achieved by unifying the functions of spacecraft control, acquisition and processing of scientific data, and timing and sequencing under a single unified data system. In the past, these functions have been performed under separate sub-systems. Modular design techniques are being studied to provide standard system components which can be assembled to fit specific needs of a given mission and minimize cost. Cost saving factors in software techniques will also be thoroughly investigated. In the very important area of reliability, fault tolerant computing concepts including self-repair, error detection codes and fail safe programs will be incorporated as necessary to achieve the desired life expectancy.

- The work at JSC emphasizes data processing operations associated with Manned Spacecraft Data Systems. Off-the-shelf processors, displays, keyboards, acquisition and control modules, and mass memory will be used to implement a fault-tolerant computer system for laboratory evaluation. This fault tolerant system will be used to define software requirements dictated by the crew involvement. In a parallel activity, techniques for predicting and measuring the reliability of fault tolerant systems consisting of multiple computers will be developed and evaluated using the laboratory system as a key data point.

- Work on holographic mass memory systems at MSFC is divided into three major areas: (a) Optical Memory Breadboard; (b) Optical Memory System; and (c) Optical Memory Components. In the area of the Optical Memory Breadboard, a 10^5 bit system containing all basic memory components is being used experimentally to study interfaces within the memory, to test new materials, components and concepts, and to identify problem areas for further investigation. The breadboard system will next be interfaced with a computer to study the computer-memory relationship and evaluate operational requirements. Work in the area of Optical Memory Systems includes system design to accomplish progressively higher storage capacity, a study of memory architecture and computer interfaces, and construction of engineering brassboards at different stages of system maturity. Fabrication of a 10^8 bit memory system will be completed by mid FY 76. By improving the memory components, the capacity of this system will be expanded to 10^9 or 10^{10} bits by the end of FY 77. The design of the 10^{12} bit memory system for space application will begin in FY 78. In the area of Optical Components, continuing investigations and testing of available materials and components are being conducted. Emphasis is being placed on critical items such as the block data composer and the holographic storage material. Optical memory materials under study at LaRC will be included in this component evaluation program.

o Work at GSFC is aimed at providing a parallel image processing system which could optically process all points of an image simultaneously to give an effective processing rate of 10^{12} bits per second. The system accepts an image directly as an input and operates on the image to extract the information desired. The so-called "Tse" computer utilizes an entire binary image as its basic computational entity, as opposed to using a single bit as the computational entity in conventional computers. The optical components required to construct the basic computer elements such as A/D converters, AND, OR and other logic elements are being developed under contract. These components will initially have 5 millisecond operating speed, and will operate on a one square inch picture with 128X128 resolution elements. Subsequently, the operating speed of these components will be increased to 100 microsecond and will be integrated to form a first generation "Tse" computer.

Thorough testing and evaluation will be conducted to establish concept feasibility and define further research requirements. The first generation "Tse" computer will have effective processing rate of 1.6×10^8 bits per second and is scheduled to be completed by the end of FY 76. In subsequent years, components combining faster speed and increased resolution elements will be developed and integrated into advanced systems to provide progressively higher processing rates, ultimately arriving at the 10^{12} bits per second goal.

Major milestones of the High Capacity Data Systems work are:

Early FY 1975 - Integrate the off-the-shelf data processing components into a fault tolerant multi-computer system appropriate for Manned Space Flight Missions.

Mid FY 1975 - Complete the design of the unified data system for deep space application.

Late FY 1975 - Complete construction of logical elements and 8 level A/D converter for the optical parallel processor.

Mid FY 1976 - Complete 10^8 bit capacity holographic memory brass board system.

Mid FY 1976 - Complete the breadboard of the deep space unified data system.

Late FY 1976 - Complete the laboratory test and evaluation of the fault tolerant multi-computer system.

Late FY 1976 - Complete the construction of the first generation "Tse" computer.

NEED AND RELEVANCY

The High Capacity Data Systems work is of primary relevance to the specific OAST focus of "User Interactive Information Systems and Monitoring" responding to the OAST emphasis of "Technology for Low Cost Exploitation of Space." The work also has applicable relevance to "Innovative Technology" and "Spacecraft and Entry System Technology" in the space matrix.

The program is focused on several areas in data systems where potential for high payoff exists in terms of reliability, speed, capacity, cost and long life. Future space missions will need data systems with diverse requirements and will place large demands on the on-board data system, and yet these systems must be provided at a reasonable cost. Our work at JPL for example, is aimed at providing a highly reliable and long life but low cost data system for deep space missions. Specifically, one of the important goals of the JPL work is to design a modular, multi-mission data system for post 1978 Mariner type missions so that cost savings of $1.3M per mission can be realized in data system acquisition. Our work at JSC, MSFC and GSFC are aimed at equally important data systems needs associated with future manned and unmanned space missions. In these future space missions, demands will be made for higher and higher capacity (10^{10}-10^{12} bits) mass information storage systems to support the advanced sensors and processors. Manned missions will require an integrated, fault tolerant data system with crew interfaces which would perform navigation guidance and control functions. On many of the deep space and near earth image collection missions, a fast (10^{12} bits/sec) on-board image processing computer would be highly desirable for extracting information from images so that reduced data rather than raw data could be transmitted over the data link to relieve the transmission capacity problem. This program aims to provide the technology required to meet the above needs. Meeting these needs will enhance this Nation's capability to gain fundamental scientific knowledge and to provide economic means for exploitation of the space environment.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	21.8	23.0	25	25	23.0	23.0
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1540	1500	1920	2220	2050	1900
IMS	100	120	180	180	180	170
TOTAL R&D	1640	1620	2100	2400	2230	2070
R&PM Resources	423	448	525	561	523	484
TOTAL VALUE	2063	2068	2625	2961	2753	2454

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
506-20-11 Advanced Digital Data Systems for Deep Space (502-33-29)	JPL	440	10	600	11	550	11
506-20-12 Multiprocessor Fault Tolerant Computer Development (502-23-33)	JSC	200	1	200	1	250	2
506-20-13 Optical Mass Memory (502-23-31)	MSFC	400	5	200	5	600	6
506-20-14 Automated Data Handling Techniques and Components (502-23-32)	GSFC	500	5.8	500	6	520	6
TOTAL		1540	21.8	1500	23	1920	25

c. Crosswalk Resource

1. 100% of resources of primary relevance to the specific OAST focus of "User Interactive Information Systems and Monitoring".

2. 50% of resources of applicable relevance to the specific OAST focus of "Innovative Technology".

3. 50% of resources of applicable relevance to the specific OAST focus of "Spacecraft and Entry Systems Technology".

TITLE: Multimission Data Transfer and Tracking

TYPE OF SPECIFIC OBJECTIVE: XX DISCIPLINE_____
STUDY______SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division --
C. Carl

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To provide spaceborne microwave components, techniques and systems which permit greater operational range, increased data transfer capacity and longer life-times for future NASA missions at reasonable cost levels. Specific targets are:

- o Demonstrate a Ku Band receiver in FY 75 with a noise figure reduced from 5 to $<$ 2 dB and with operating life increased from 2 to 4 years for TDRSS and Shuttle.
- o In FY 75 devise codes for communicating through the solar corona to reduce data loss from typically 10 days to 2 days for outer planet missions.
- o Demonstrate in FY 76 a standardized micro-miniature dual frequency spacecraft transponder featuring a 30% cost reduction (to$\sim$ \$130K) and operating life increased from 4 to 8 years.
- o Demonstrate a solid state Ku Band transmitter in FY 76 to reduce power requirements by a factor of two, provide less system complexity and increase the operating lifetime from 2 to 4 years.
- o In FY 76, select a more efficient code that increases data transfer capability by a factor of 2.
- o Investigate and verify techniques in FY 77 to improve the efficiency of high frequency tubes (4-20 GHZ) by up to 50%. (Currently 15-30%)
- o In FY 77 demonstrate a dual frequency line-fed conical antenna with 60 db gain at X-band.

APPROACH

The emphasis in this objective is the improvement of microwave systems to provide the operational performance capability in data transfer and tracking required to permit the execution of NASA's future planned missions. Recognizing the need for cost effectiveness, a central element is the generation of lower cost systems by use of modular concepts and improved techniques to avoid costly fabrication processes, and procedures. Technology efforts are conducted at various NASA centers depending upon the particular task involved or type of mission application. In planetary applications, the efforts are largely centered at JPL and include development of large, high gain, unfurlable antennas, microminiature modular transponders, and coding techniques for use under normal and adverse propagation conditions. The emphasis at GSFC is on solid state transmitters and low noise receivers for near earth satellites, while LeRC's concentration involves power tube technology.

- o JPL is investigating means of improving data transfer through the solar corona by coupling non-coherent modulation/demodulation techniques and improved coding techniques with a better understanding of wave propagation through the solar corona. The latter is being derived using previously obtained data and data to be received from MVM'73 S-X band experiment and comparing these against a theoretical model for propagation through turbulent media. For coding improvement, studies in FY 73 indicated that the use of an incoherent telemetry channel with multi-frequency shift keying allows the use of a more efficient code design. Simulation software is currently being developed for an assessment of the coding gain and decoder complexity using this technique. Finally an analysis will be made to determine the best trade-off between modulation and code complexity for design optimization.

- o JPL is also combining advances in integrated circuits and associated microminiature techniques with an analysis of the transponder requirements for future planetary missions to provide a low cost, standard, modular S/C transponder with dual frequency capability. In addition to improved reliability and lower cost, improved metric tracking performance will be satisfied for navigation and radio science applications. The program is being conducted in three phases. A discrete component circuit board version will be completed in FY 74. The next phase will demonstrate a microminiature version using beam-leaded parts on ceramic substrates to further reduce the number of parts and weight. Finally the transponder will incorporate digital low-frequency circuitry and integrated semiconductors and reactive circuit elements on a single chip. Both laboratory test and analysis, and flight experiments are planned to complement this development.

- High gain deep space antenna technology is being conducted at JPL to provide designs offering the best combinations of size, cost, weight and RF efficiency. Analyses and tests have narrowed the reflector design to a conical shape which provides a potentially large diameter, furlability, light weight, and a singly curved mechanical surface. Trade-offs of various modes of RF source feeds including the use of subreflectors were made by conducting model tests. The results indicate that a line source feed is potentially more cost effective than other designs while providing good RF efficiency and added weight savings. Currently line feeds are being designed to optimize the RF efficiencies at both S and X band for tests with various size antennas up to 5 meters. Future efforts include the development of beam steering techniques for application to antennas larger than 5 meters.

- At LeRC, a three phase approach for increasing the efficiency of microwave power tube amplifiers is being pursued. First, they will study inherent tube losses such as heater, beam focusing and RF losses. In the second phase, methods of reducing the losses and uses of multi-stage depressed collectors (MDC) will be analyzed and experimentally evaluated to establish feasibility and performance trade-offs. Finally, existing tubes will be modified to add experimental designs of MDC's with beam refocusing and tests will be conducted to optimize the MDC design for maximum tube efficiency.

- To permit improved wide band data links, GSFC is investigating application of integrated circuits, varactor technology, and microstrip techniques to develop a low noise parametric amplifier. The development makes use of previously established circuit techniques at lower frequencies and combines this with higher frequency varactor components

Effective Systems" in OAST's focused activities. Currently planned missions in the late 1970's and early 1980's can only be successfully conducted by technology advances which provide cost effective data return. The objective of this task is to provide the needed capability. For example, the use of the higher frequency X and Ku Bands will increase the information return by factors of 10 and more without any increase in equipment weight or power. This technique and associated technology to be developed will permit NASA to fulfill its mission of space exploration cost effectively by providing more information per dollar outlay and avoiding costly additional missions to obtain sufficient data for proper conclusions.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	47.4	37.8	37.5	35	35	35
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1364*	1575	1635	1600	1650	1700
IMS	270	145	150	160	160	170
TOTAL R&D	1634	1720	1785	1760	1810	1870
R&PM Resources	789	650	650	570	570	570
TOTAL VALUE	2423	2370	2435	2330	2380	2440

* Does not include FY 73 NOA of $31K added to support the FY 74 program.

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man Power	BEST ESTIMATES FY 76 Net $ (K)	BEST ESTIMATES FY 76 Man Power
506-20-21 Microminiature Transponder Development (502-23-03)	JPL	389*	11	875	8.3	385	6
506-20-22 Microwave Components & Sys (502-23-12 &33-92)	JPL	645	12.9	535	10	700	12
506-20-23 Microwave Power Tube Technology (502-23-01)	LeRC	195	20	140	18	400	18
506-20-24 Microwave Near Earth Data Transfer and Tracking (502-23-11)	GSFC	135	1.5	25	1.5	150	1.5
Antenna Techniques (502-33-92)	LRC	-	2	-	-	-	-
TOTALS		1364*	47.4	1575	37.8	1635	37.5

*Does not include FY 73 NOA of $31K added to support the FY 74 program.

c. Crosswalk Resource

1. 70% of resources of primary relevance to "User Interactive Information Systems and Monitoring" aspects of OAST focus.

2. 30% of resources of primary relevance to "Lower Cost and High Performance Effective Systems" area.

3. 50% of resources of applicable relevance to "S/C and Entry Systems Technology.

4. 10% of resources of applicable relevance to "Shuttle Exploitation Technology".

5. 10% of resources of applicable relevance to "Innovative Technology".

TITLE: High Rate Data Transfer & Tracking

TYPE OF SPECIFIC OBJECTIVE: XX DISCIPLINE____ STUDY______SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division -- C. Carl

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To develop technology leading to laser systems which can provide: 1) very high rate data transfer from satellite to satellite and satellite to ground; and 2) improved tracking capability to determine precise satellite position for earth applications. Specific targets are:

- In FY 75, demonstrate the operational readiness of the 1.2 meter aperture tracking telescope facility which will serve as the precision ground station for laser data transfer and tracking experiments in space.

- In FY 76, complete the evaluation of a space carbon dioxide laser transceiver engineering model, capable of 300 megabits per second data transfer from Earth orbit to ground.

- In FY 77, prove the feasibility of neodymium-YAG technology application to data transfer by operation of a 400 megabits per second laboratory breadboard constructed of space-qualifiable components (current capabilities 15 MBPS).

- Through laboratory system tests by FY 77, provide technology meeting the EOPAP requirement for space-to-space tracking with an accuracy of 2 centimeters (current accuracy 2-10 meters).

APPROACH:

High rate data transfer and laser tracking technology is primarily conducted at Goddard Space Flight Center, with related basic laser research sponsored directly by Headquarters. Specific areas of work to be pursued are as follows:

- Laser Data Transfer - This area embodies a comprehensive program in component technology, system studies and space-integrated package development, which will lead to experiments showing the feasibility of lasers for very high rate data transfer from space. Two laser technologies are being developed: the carbon dioxide (10.6μ wavelength) and the neodymium-YAG (1.06μ); the former becuase of its near-term maturity for space use and the latter because of its future potential capability. In the components area, the essential parts of a laser data transfer system (lasers, optics, modulators and detectors) are being developed. System studies are used to define performance for candidate missions and determine application configurations and integration requirements. To validate the resultant designs, the program will produce, as a prelude to a flight experiment program, engineering models of integrated (optics and electronics) laser packages which will meet typical mission performance requirements. This work will include the final design of a carbon dioxide transceiver package, geared to two-way 300 megabits per second data transmission from synchronous orbit to ground or low-orbit vehicle. Initial planning discussions are underway with the Air Force to launch this package as part of a joint NASA/DOD experiment in FY 79.

- Laser Tracking Systems - This area provides technology developments to enable lasers to track spacecraft - both in range and range-rate (velocity) - with extremely precise accuracy. The key difference between data transfer and tracking applications is that tracking requires much higher power lasers, must accommodate higher Doppler frequency shifts, and detect basically different information. To this end, the program is geared toward developing higher power neodymium-YAG lasers and wider-bandwidth tunable carbon dioxide lasers for spacecraft use. A new ground station detection system is under development which will resolve ranging signals to the sub-centimeter level. Following the approach of the data transfer program, these component developments will lead to a system demonstration of advanced tracking techniques in the laboratory for potential space applications in the early 1980's.

Supporting both the data transfer and tracking activities are university research grants (managed from Headquarters and GSFC) and a new 1.2 meter aperture ground station at Goddard.

Major milestones of the High Rate Data Transfer and Tracking Objectives are:

FY 75 - As part of the carbon dioxide transceiver engineering model, complete tests on a waveguide local oscillator.

FY 75 - Make 1.2 meter telescope ground station operational with 1 sec tracking accuracy.

FY 75 - Demonstrate 5% efficient neodymium-YAG photo multiplier detector for both data transfer and tracking applications.

FY 76 - Complete testing of the carbon dioxide transceiver engineering model for 300 megabit per second data transfer use.

FY 76 - Evaluate ground tracking detector system providing ranging to an accuracy of 0.2 centimeters.

FY 76 - Provide a 1/2 watt diode-pumped conduction-cooled neodymium-YAG laser suitable for space qualification for use in both data transfer and tracking programs.

FY 77 - Demonstrate 4000 hour carbon-dioxide laser lifetime for space data transfer use.

FY 77 - Complete testing of an operationally realistic 400 megabit per second neodymium-YAG data transfer system in the laboratory using space-qualifiable components.

NEED AND RELEVANCY:

The laser data transfer work has primary relevance to the OAST focus of "User Interactive Information Systems and Monitoring" in that laser systems will be a cost-effective alternative to microwaves when rates exceed 200 megabits per second for earth resource satellites and microwave spectrum allocations are fully committed. The laser tracking work has primary relevance to the OAST focus of "Lower Cost and Higher Performance Effective Systems" to supply precision tracking capability to Earth and Ocean Physics Applications Program missions. This tracking will enable satellites to be "orbital reference points" to determine tectonic plate movements, useful in earthquake prediction and other geophysical measurements. The laser data transfer work also has applicable relevance to the OAST focus of "DOD Support" since the Air Force is making use of this technology in planning programs to satisfy specific DOD missions.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	13.2	14.4	15.3	15.0	13.5	13.0
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	1,361*	1,525	1,740	1,900	1,750	1,600
IMS	170	175	200	200	175	150
TOTAL R&D	1,531	1,700	1,940	2,100	1,925	1,750
R&PM Resources	470	500	500	500	500	450
TOTAL VALUE	2,001	2,200	2,440	2,600	2,425	2,200

*Does not include FY 73 NOA of $324K added to support the FY 74 program.

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	NEGOTIATED FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	BEST ESTIMATES FY 75 Man Power	BEST ESTIMATES FY 76 Net $ (K)	BEST ESTIMATES FY 76 Man Power
506-20-31 Optical Data Transfer Research (502-03-12)	HQ	0*	0.1	140	0.1	140	0.1
506-20-32 Optical Data Transfer Systems (502-23-15)	GSFC	656**	10.0	1020	10.7	1150	10.7
506-20-33 Optical Tracking Systems (502-03-11, 23-18)	GSFC	555	2.8	365	3.6	450	4.5
Laser Data Transfer Flight Experiment Def. (502-23-02)	GSFC	75	0.2	--	--	Proposed FY 76 New Start	
Technology Forecasting for Space Comm. (502-23-14)	GSFC	75	0.1	--	--	--	--
TOTALS		1361	13.2	1525	14.4	1740	15.3

*Does not include FY 73 NOA of $180K added to support the FY 74 program.

**Does not include FY 73 NOA of $144K added to support the FY 74 program.

c. Crosswalk Resource

1. 60% of resources of primary relevance to the specific OAST focus of "User Interactive Information Systems & Monitoring".

2. 20% of resources of primary relevance to the specific OAST focus of "Lower Cost and Higher Performance Effective Systems".

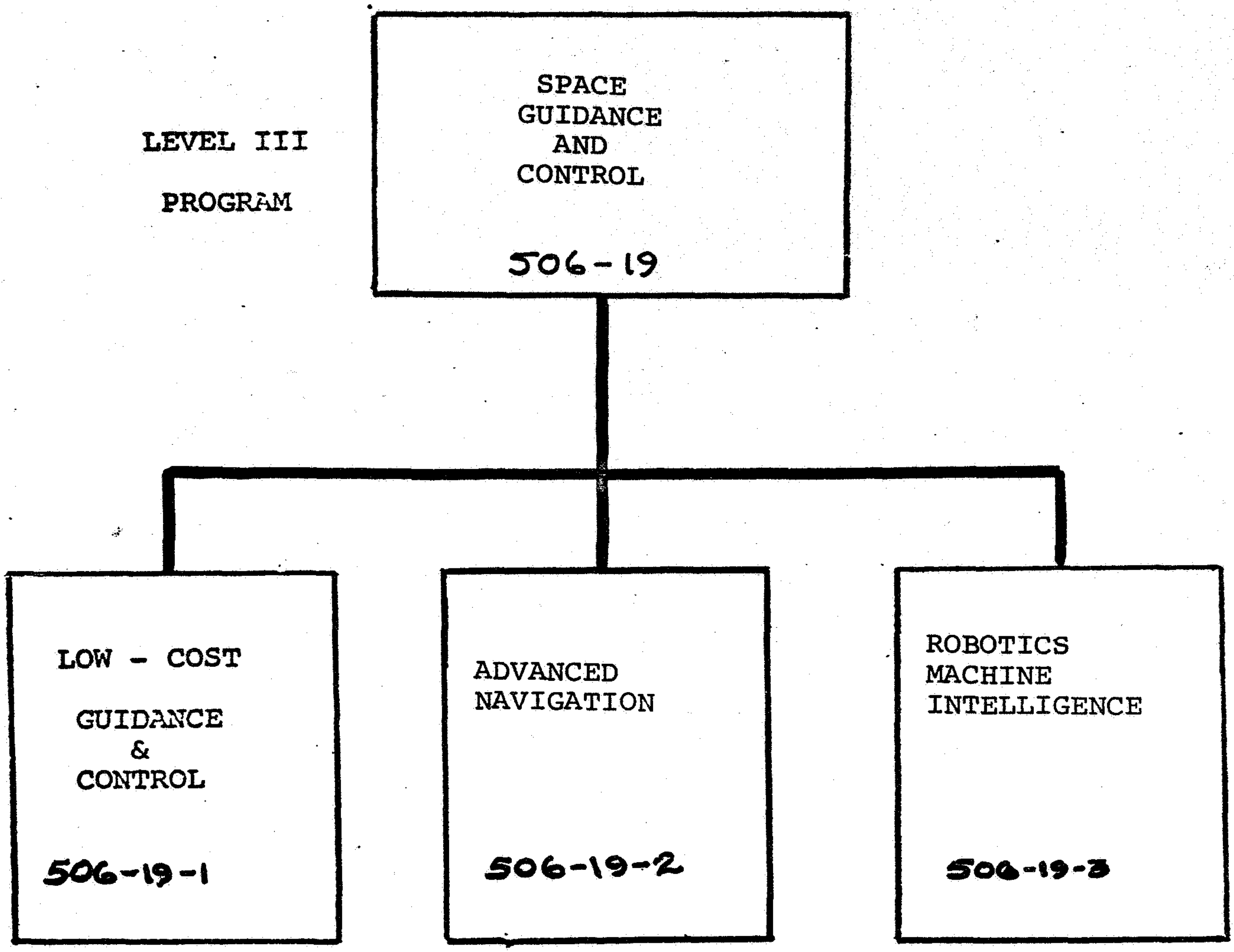
3. 20% of resources of primary relevance to the specific OAST focus of "Basic Research".

4. 50% of resources of applicable relevance to the specific OAST focus of "Spacecraft and Entry Systems Technology".

5. 50% of resources of applicable relevance to the specific OAST focus of "DOD Support".

SPACE GUIDANCE AND CONTROL WORK BREAKDOWN STRUCTURE

LEVEL III & IV



SPACE GUIDANCE AND CONTROL

Program Objective

Provide the technology necessary to control and maneuver manned and unmanned aerospace vehicles in the exploration and exploitation of space at minimum costs while maintaining at improving performance standards. We will demonstrate:

- Low cost guidance and control components and concepts to reduce production costs 50% or more.
- Advanced navigation techniques to increase trajectory determination accuracy by a factor of ten.
- Approach guidance technology for planetary missions to minimize fuel usage and permit payload increases of up to 50%.
- Problem-solving software and hardware, and techniques for integrating sensors and control devices to permit operation of unmanned vehicles or robot machines.

Location, orientation and operation of space vehicles and experiments are critical to mission success. Research on longer life components and modular system concepts will lead to simplified functional systems having greater versatility and reduced costs. Refinements of planetary ephemerides and improved data processing techniques will permit more precise location of space vehicles in relation to their planned trajectories. Synthesis and demonstration of autonomous approach guidance technology will provide improved accuracy and more effective use of available payload in outer planet exploration. Research on logic systems and techniques for approximating human cognitive processes offers new capabilities and concepts for near-autonomous operation of machines and vehicles in alien environments.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	55	55	53	49	47	45
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	2501*	2750	3290	3050	3050	2750
IMS	222	165	122	110	90	80
TOTAL R&D	2723	2915	3412	3160	3140	2830
R&PM Resources	1216	1059	809	739	701	665
TOTAL VALUE	3939	3974	4221	3899	3841	3495
Est..Net Costs	2609	2750	3300	3000	3100	2750

*Does not include FY 73 NOA of $350K added to support the FY 74 program.

TITLE: Low-Cost Guidance and Control

TYPE OF OBJECTIVE: X DISCIPLINE ____ STUDY
____ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division - C. E. Pontious

STATEMENT OF OBJECTIVE AND TARGETS:

Objective: To investigate and verify novel guidance and control concepts which offer improved performance and lifetime, yet provide the potential for major cost savings over current state-of-the-art (FY 74) systems.

Targets:

- o By FY 75, implement and flight test a laser gyro inertial navigation system capable of 0.1°/hr accuracies, MTBF of 4 years, and production costs of less than $50K.
- o By FY 76, conduct analyses and breadboard hardware evaluations of an Annular Momentum Control Device (AMCD) for three-axis spacecraft stabilization to 0.1 sec and potential control system weight and volume reductions to .02 lb/ft-lb -sec and .2 in^3/ft-lb-sec, respectively. (Representing a factor of 10 improvement over existing systems.)
- o By FY 77, mechanize and test a breadboard programmable attitude control electronics with fault tolerant capability with a life potential of greater than eight years.
- o By FY 78, determine through ground simulations and contracted studies the design feasibility of adaptable control system software for arbitrary spacecraft configurations which permits reduction in recurrent software costs (target of 20% of present costs) and significantly increases software reliability through reuse.

- By FY 79, mechanize and test a breadboard Extended Life Attitude Control System (ELACS) with a 0.1° pointing accuracy and a lifetime potential of more than ten years with functional redundancy.

APPROACH:

Research on low-cost guidance and control for space applications is being conducted at ARC, LaRC, GSFC, JPL, and MSFC. Emphasis is placed on low-cost components at LaRC, GSFC and MSFC and on complete systems at LaRC and JPL. Innovative component concepts that show significant promise of long-life, low-cost, and/or multiple-use are being evaluated in laboratory and simulation tests. The new systems are being designed to minimize their sensitivity to satellite/spacecraft configuration. As a result, they will have a wider range of applications, reducing costs and improving reliability. Current activities include:

- Laser gyros will be improved at MSFC by: the use of low coefficient of expansion materials for the gyro holding block, fixed bias cells, reduction of outgassing materials, and non-magnetic bias devices. A proto-type strapdown inertial navigation system using laser gyros is being built for laboratory and flight testing.

- Magnetic suspension bearings are being designed at GSFC to support momentum wheels or torquers. These bearings will allow reductions in both weight and power, with an increase in operating lifetime. Prototypes are presently being tested to determine their characteristics.

- Advanced motors and actuators using ironless armatures are being designed at GSFC. The high efficiency (no magnetic loss) will result in power savings of 20% and significantly improve control system response.

- A prototype of an infrared horizon sensor has been delivered to LaRC where it will undergo extensive performance tests using a simulated earth. These tests will be conducted for various atmospheric conditions.

- Control moment gyro testing will continue at LaRC to establish performance and life characteristics. A prototype annular momentum control device is being designed and will be tested. Its application to three-axis control will be determined. Adaptable modular software, which permits automated and reduced-cost implementation of spacecraft guidance and control systems, is also being developed.

- An extended life attitude control system is being designed and elements of it are being tested at the component and subsystem level. This effort, underway at JPL, includes detailed analysis, derivation and demonstration of suitable algorithms for programmable fault-tolerant electronics, and mechanization and testing of a breadboard system. Major hardware subsystems are an inertial reference unit, ceramic image dissectors and charge coupled devices for optical sensors, re-programmable processor, attitude control electronics, and actuators.

- An all-sky pointer reference system is undergoing analysis and simulation at ARC to determine its performance capability. A breadboard system will be built and tested on an air bearing simulator. Flight hardware design guidelines will be generated from these activities.

NEED AND RELEVANCY:

In order to meet the objectives of space research, it is necessary to have guidance and control systems that can provide the accuracy required for the scientific instrument measurements for given missions. This must be accomplished in the most cost-effective manner. Reducing costs of the guidance and control systems while improving their accuracies can effectively reduce mission costs. To do this, new concepts for sensors, actuators, controllers, and computers which stress flexibility and usability in a variety of missions are under investigation in this program.

The results of this program have primary relevance to "Lower Cost and High Performance Effective Systems" and "S/C and Entry Systems Technology".

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	29	28	20	18	17	16
FUNDING REQUIREMENTS (K Dollars)						
NET R&D	981*	1000	840	800	800	800
IMS	215	158	122	110	90	80
TOTAL R&D	1196*	1158	962	910	890	880
R&PM RESOURCES	1145	988	774	704	666	630
TOTAL VALUE	2341*	2146	1736	1614	1556	1510

*Does not include FY 73 NOA of 100K added to support FY 74 program.

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
506-19-11 (502-23-42) Inertial Comp.	MSFC	150	4	225	4	0	0
506-19-12 (502-23-43) Adv. Comp. for Prec. Systems	GSFC	175	6	125	6	200	6
506-19-13 Adv. Space Control Systems (502-23-41 & 44)	LaRC	300	12	300	11	300	7
506-19-14 (502-23-46) ELACS	JPL	321*	4	350	7	340	7
(502-23-47) All Sky Pointer	ARC	35	3	0	0	0	0
TOTALS		981*	29	1000	28	840	20

*Does not include FY 73 NOA of 100K added to support FY 74 program.

c. Crosswalk Resources

1. 60% of resources of primary relevance to "Lower Cost and High Performance Effective Systems".

2. 40% of resources of primary relevance to "S/C and Entry Systems Technology".

3. No applicable relevance is advocated at this time.

TITLE: Advanced Navigation

TYPE OF SPECIFIC OBJECTIVE: XX DISCIPLINE
____STUDY ______SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division - C. E. Pontious

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To derive and verify advanced navigation techniques incorporating new ground and on-board measurements and software into a navigation system which minimizes trajectory correction requirements, enables efficient gravity-assists, and permits precise scientific observations, increased mission opportunities, and lower operational cost for future space exploration. Specific targets are:

- By FY '75, demonstrate the ability of S-X band multi-station radiometric data and long focal length bright target/star imaging data to reduce effects of dominant error sources by a factor of ten and yield corresponding increases in accuracy, propellant savings and mission design flexibility.

- Derive and validate in-flight approach guidance techniques which yield .25 micro-radian measurement accuracies in 6 hour turnaround times and can allow up to 50% payload increases through onboard propellant savings for outer planet missions; with satellite/star techniques to be available by FY 74 and comet and asteroid measurement technology to be available by FY 76.

- By FY 77, demonstrate outer planet satellite ephemerides programs, which improve present (FY 74) ephemerides by factors of 5-20 and allow a factor of 50 reduction in the computer time required to generate satellite trajectories resulting in project cost savings and increased mission operations flexibility.

- By FY 78 demonstrate in the laboratory an optical navigation system using ground based data processing which reduces the data processing time from the 6 hours currently required to 2 minutes while retaining the accuracy to within 20%. By FY 80 design and validate in flight a fully autonomous system with the capability of on-board flight path control to 1 km within six minutes of final measurement for small body rendezvous or fly-by missions.

APPROACH:

Research on advanced navigation for space applications is conducted primarily at JPL. Emphasis is placed on the total navigation system including mathematical tools associated with filtering and modeling, onboard hardware including sensors and data processors. Present operational navigational technology (MK I) is characterized by the use of ground-based radio tracking measurements, data processing, and control. This effort will provide MK II navigation technology which uses onboard navigation measurements in concert with Earth-based measurements. It will also establish the basic technology for MK III navigation capability, characterized by autonomous processing of onboard measurements and limited autonomous onboard control. Critical related system concepts will be evaluated through experimental demonstrations on ongoing and planned planetary missions. Current flight experiments include:

- MM'71 OND: Analysis of the approach phase and in-orbit Phobos-Diemos/star data is completed. The results and technologies developed from the Optical Navigation Demonstration will be documented and transferred to Viking, MJS, and future missions.

- MVM'73: Efforts will be coordinated with the MVM'73 project for the demonstration of improved orbit determination through the use of dual-frequency (S-X) and multi-station (both range and Doppler) radiometric tracking data, long focal length on-board imaging. The data will be processed with advanced estimation software capable of handling these new data types.

These demonstrations are complemented by a focused technology program, which addresses the key problems in MK II and MK III systems implementation. Major elements of this program are:

MK II: ONBOARD MEASUREMENTS/GROUND PROCESSING

- SATELLITE SYSTEM DYNAMICS MODEL

  A general theory for outer planet satellite motion will be derived with the aid of computer algebraic manipulation routines and the use of Poisson series expansions for use in the determination of spacecraft position (relative to the satellites and the star background) during planetary approach modes. The software capability will be demonstrated by comparison with numerical integration and by processing selected samples of earth-based observations.

- OPTICAL GUIDANCE MEASUREMENT TECHNOLOGY

  Major emphasis will continue to center on the sensor characterization program. After detailed star-satellite tests with selenium vidicons, simulations will be built for comets and asteroids; tests on these targets will be conducted. Advanced sensors, such as CCD's which offer increased performance at lower cost, will be tested in a controlled simulation allowing development of realistic error models and comparison with other sensor candidates.

- OPTICAL GUIDANCE SOFTWARE

  The effort will develop the measurement processing software needed to convert these measurements into navigation information; calibration and error modeling will be performed. Models of characteristics of expected targets and associated sensor performance and calibration accuracy will be implemented. Automation of ground data extraction software is a preliminary to the eventual on-board autonomous measurement processing.

- ADVANCED ESTIMATION AND PERFORMANCE PREDICTION

  A program to determine the navigation accuracy of a planet orbiter will be developed, including error equations for new data types. Accuracy analyses will be performed to evaluate data characteristics and identify mission situations for which the new data types offer significant advantages over conventional data. Potential measurement techniques to be considered include radar bounce measurements, satellite/asteroid surface feature analysis, advanced radiometric, and on-board optical.

- MULTIPLE MANEUVER STRATEGY

  This activity will continue to establish the theoretical formulations and associated software programs for optimal flight path control strategies for multiple maneuver and/or multiple target missions which demonstrate significant ΔV (propellant) savings over current techniques. In addition, advanced techniques in ΔV estimation and propellant margin design will be developed. Application of optimal maneuver strategy techniques will be made to such missions as multi-planet, cometary, and orbiter tours of planetary satellites.

MK III: ONBOARD MEASUREMENTS/ONBOARD PROCESSING

- AUTONOMOUS ON-BOARD NAVIGATION

  This activity will establish cost-effective on-board navigation objectives to meet future mission demands. Earth-based vs on-board tradeoffs will be made to determine mission phases for which autonomous guidance and navigation can achieve one or more of the following: greater science return through adaptive instrument pointing, tighter flight path control and/or science pointing accuracy, reduced ground-system complexity and cost, shorter reaction-time requirements, and improved navigation system reliability. An interdisciplinary study team has been formed to provide the necessary task integration to define the software and hardware design requirements leading to laboratory demonstrations to confirm flight readiness. Technical considerations include on-board algorithms, extent of on-board autonomy, sensor characteristics, pattern recognition, maneuver and science pointing hardware configuration, error models, and cost. Final task goal is directed at flight demonstration on a pre-1985 mission.

- LANDING SITE SELECTION

  The objective of this work at LaRC is to develop an on-board Video landing site selection system. This system could be used to select non-hazardous landing sites for post '75 Viking lander missions, or for rendezvous or landing on small planetary bodies. A breadboard system containing a video camera will be developed for landing on 3-dimensional simulated Mars terrain models. Sun angle effects and scan pattern variations will be considered.

Major milestones of the Advanced Navigation research are:

Early FY 75 - Complete ground demonstration of optical guidance measurement sensors.

- Complete prelminary analysis of autonomous on-board navigation system requirements.

Mid FY 75 - Complete final design of advanced estimation and performance prediction software for orbit determination.

Late FY 75 - Deliver finalized performance prediction software.

- Complete study of video guidance systems.

Mid FY 76 - Complete design of small body dynamics model.

- Complete final design of autonomous on-board navigation system.

Late FY 76 - Orbiter maneuver strategy technology ready.

NEED AND RELEVANCY:

Many of the future candidate missions for the end of this decade and through the 1980's will be performance/payload limited by constraints imposed on total mission costs. Advances in deep space navigation technology offer both greater probability of mission success and increased delivery accuracy capability leading to a maximum science value return for any given payload. New and improved measurement data types, orbit determination techniques, maneuver strategy technology and maneuver execution strategies will influence spacecraft design through the reduction of on-board propellant requirements. Propellant savings will come from both mission design capitalizing on gravity assist-braking as well as savings in navigation correction propellant.

Missions to bodies characterized by long round-trip communication time lags relative to event sequences will require some degree of on-board autonomous navigation capability. Such situations can arise from uncertainties in ephemerides for "massless" targets (comet/asteroid flybys/rendezvous) and atmospheres (outer planet probes), multiple encounters with small massive bodies (satellite tours), Earth occultation during time critical phases, and on sample return ascent trajectories.

The Advanced Navigation Program is directed at solving the problems associated with meeting the navigation requirements for future space exploration. It has primary relevance to "S/C and Entry Systems Technology" and applicable relevance to "Lower Cost and High Performance Effective Systems".

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	15	15	17	15	15	14
FUNDING REQUIREMENTS (K Dollars)						
NET R&D	770	700	900	800	800	700
IMS	7	7	-	-	-	-
TOTAL R&D	777	707	900	800	800	700
R&PM RESOURCES	36	36	-	-	-	-
TOTAL VALUE	813	743	900	800	800	700

b. RTOP Resources

RTOP Number & Title	Center	NEGOTIATED FY 74 Net $ (K)	FY 74 Man Power	BEST ESTIMATES FY 75 Net $ (K)	FY 75 Man Power	FY 76 Net $ (K)	FY 76 Man Power
506-19-21 Guidance and Navigation for Unmanned Planetary Vehicles (502-33-91)	JPL	670	14	700	14	900	17
506-19-22 Video Guidance for Space Missions (502-33-95)	LaRC	100	1	0	1	0	0
TOTALS		770	15	700	15	900	17

c. Crosswalk Resource

1. 100% of resources of primary relevance to "S/C and Entry Systems Technology".

2. 30% of resources of applicable relevance to "Lower Cost and High Performance Effective Systems".

TITLE: Robotics/Machine Intelligence

TYPE OF SPECIFIC OBJECTIVE: X DISCIPLINE___ STUDY___ SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Guidance, Control and Information Systems Division - C. E. Pontious

STATEMENT OF SPECIFIC OBJECTIVES AND TARGETS:

Objective: Establish a technology base in robotics and semiautonomous control of unmanned machines or vehicles to support lunar and planetary surface explorations, remotely piloted vehicles and automated fabrication facilities. Specific targets include:

- In FY 1975, integrate manipulators, sensors, control computer and rover vehicle and begin tethered operations in a laboratory environment to evaluate control software and demonstrate robot operation.

- In FY 1976, conduct tethered system operation and evaluations. Initiate software and system modifications necessary for untethered operations.

- In FY 1977, demonstrate semiautonomous operations of an untethered robot roving vehicle in a natural environment. Modify system to incorporate dual manipulators and techniques for complex outdoor scene analysis.

- In FY 1978 and subsequent years, continue system development and evaluate the balance between autonomy and man-machine interaction for the efficient conduct of remote operations. Provide design data for semiautonomous planetary roving vehicles.

APPROACH:

Research in robotics/machine intelligence is performed principally at JPL with assistance from industry and universities supported by a HQ grant program. The program has two major facets. Theoretical studies are being conducted in university and industrial laboratories to complement those at JPL and to expand the machine approximation of human cognitive processes. At JPL, a robot demonstration program is being pursued to provide practical tests and evaluations of machine intelligence concepts, define research requirements and develop design guidelines for system applications.

- Under technical monitorship from JPL engineers, HQ sponsors several research grants or contracts with major centers of artificial intelligence research. These grants and contracts provide access to the newest and most advanced concepts in autonomous machine inte-ligence. Currently, emphasis is centered on the development of programming theory at the University of Maryland to permit more effective use of computer capacity; interactive scene analysis at the Stanford Research Institute to permit machine interpolation of the sensed environment; virtual function integration at the California Institute of Technology to permit early simulation of complex systems; and robot problem solving techniques at Bolt, Beranek and Newman, Inc. to provide efficient languages for machine cognition. Results from each of these theoretical studies are incorporated into the JPL demonstration program as they become available to improve that program or test the validity of those results.

- At JPL, a robot roving vehicle is being assembled to demonstrate semiautonomous machine operations. The program consists of two major phases. In the first phase, appropriate manipulators, sensors, control computers and a wheeled vehicle are being integrated to provide a breadboard roving vehicle. This vehicle will be operated in a tethered, laboratory environment to evaluate controlling software, system operational procedures and vehicle characteristics. In the second phase, necessary modifications to the vehicle subsystems, software and control procedures will be accomplished and the modified system will be operated semiautonomously in an outdoor environment. In subsequent years, new concepts in manipulators, sensors and control software will be incorporated in the demonstration system and evaluated to provide a design base for planetary rovers and remotely controlled vehicles.

Major milestones of the Robotics/Machine Intelligence program are:

Mid FY 75 - Complete manipulator-TV/laser sensor integration.

Late FY 75 - Begin tethered vehicle operations.
Begin test and evaluation of man-machine software.

Mid FY 76 - Complete vehicle-manipulator-sensor integration.
Conduct tethered operations of full system.

Late FY 76 - Complete tactile sensing development.
Begin outdoor site preparation.
Begin radio link development.
Continue man-machine experimentation.

Mid FY 77 - Integrate additional sensors with system.
Complete system modifications for untethered outdoor operation with a radio link.
Demonstrate vision software modifications for complex outdoor scene analysis.

Late FY 77 - Complete dual manipulator modification.
Conduct operations of untethered vehicle outdoors in semiautonomous mode.

NEED AND RELEVANCY:

Machine systems capable of performing intelligence functions such as scene analysis, decision making and adaptive control can substantially enhance our ability to explore planetary surfaces and operate in hostile environments. Such systems would avoid the communication time delays (45 minutes round trip to Mars) involved in direct control of planetary surface exploration and permit adaptive, semi-autonomous operations which could both increase our rate of information acquisition and reduce system support costs necessary under currently available technology. Similarly, such systems could operate in hostile environments as an extension of man's capability, thereby, avoiding the cost of man-rating systems and eliminating risks to man's safety. Finally, advances in automation or machine control can be applied to manufacturing processes to reduce labor costs, enhance standardization and ensure reproducibility of complex devices and processes.

Research in robotics/machine intelligence is primarily relevant to the specific OAST focus on Basic Research, but has important applications to Innovative Technology, Spacecraft and Entry Systems Technology, and Lower Cost and Higher Performance'Effective Systems.

RESOURCES

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	11	12	16	16	15	15
FUNDING REQUIREMENTS (K Dollars)						
Net R&D	750*	1050	1550	1450	1450	1250
IMS	0	0	0	0	0	0
TOTAL R&D	750*	1050	1550	1450	1450	1250
R&PM Resources	35	35	35	35	35	35
TOTAL VALUE	785*	1085	1585	1485	1485	1285

b. RTOP Resources

		NEGOTIATED FY 74		BEST ESTIMATES FY 75		FY 76	
RTOP Number & Title	Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power
506-19-31 Artificial Intelligence (502-03-31)	HQ	0*	1	250	1	250	1
506-19-32 Artificial Intelligence for Integrated Robot Systems (502-03-32)	JPL	750	10	800	11	1300	15
TOTALS		750*	11	1050	12	1550	16

* Does not include FY 73 NOA of $250K added to support FY 74 Program.

c. Crosswalk Resources

1. 100% of resources of primary relevance to the specific OAST focus on Basic Research.

2. 60% of resources are applicable to Spacecraft and Entry Systems Technology focus.

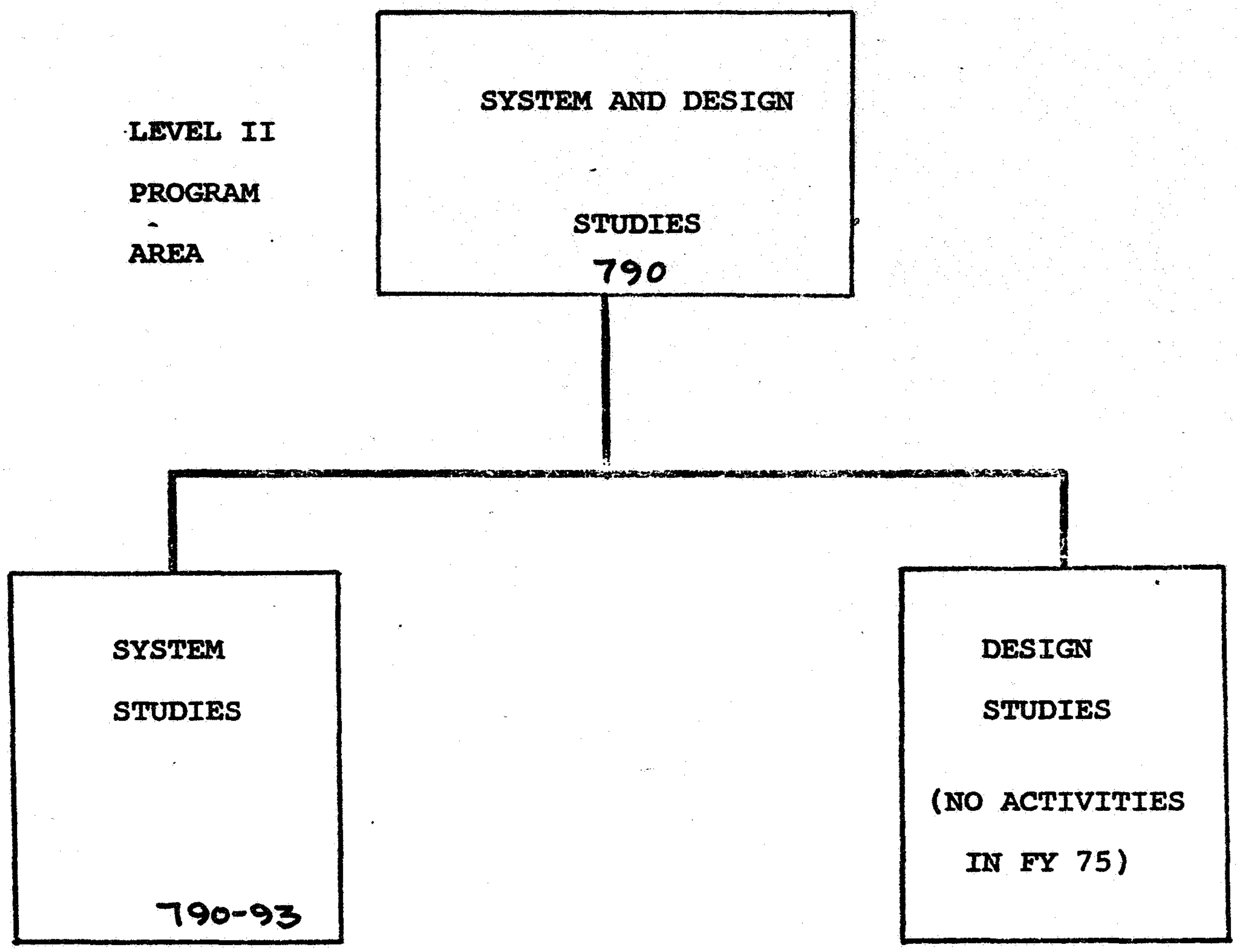
3. 40% of resources are applicable to Innovative Technology focus.

4. 20% of resources are applicable to Lower Cost and Higher Performance Effective Systems focus.

SPACE AND NUCLEAR WORK BREAKDOWN STRUCTURE SYSTEM

& DESIGN STUDIES,

LEVEL II & III



LEVEL III PROGRAM

<u>Systems and Design Studies</u>

<u>PROGRAM AREA GOAL</u>

The goal of this program area is:

> Identify areas for future technology focus including continuous examination of current technology objectives to ensure their appropriateness and payoff; also, provide the necessary technical and economic decision base to support the selection of future "system and experimental programs".

System and design studies involve <u>only</u> paper studies. They are conducted inhouse and/or on contract. They are generally interdisciplinary in nature and their output is useful to all technical disciplines rather than a single discipline.

SPACE SYSTEMS STUDIES

Program Objective

Identify and evaluate the technology requirements of advanced space systems and assess the effects of technology advances on space program alternatives.

Program

The program objective is accomplished through studies in each of the general areas of space science, applications, manned space flight, and space transportation. Particular emphasis is placed on studies to:

(1) Define criteria and resulting requirements for technology readiness of planned and projected future missions. Define associated technology development program plans.

(2) Evaluate the effects on planned, projected, and optional future missions, of incorporating planned technology advances or available technology alternatives.

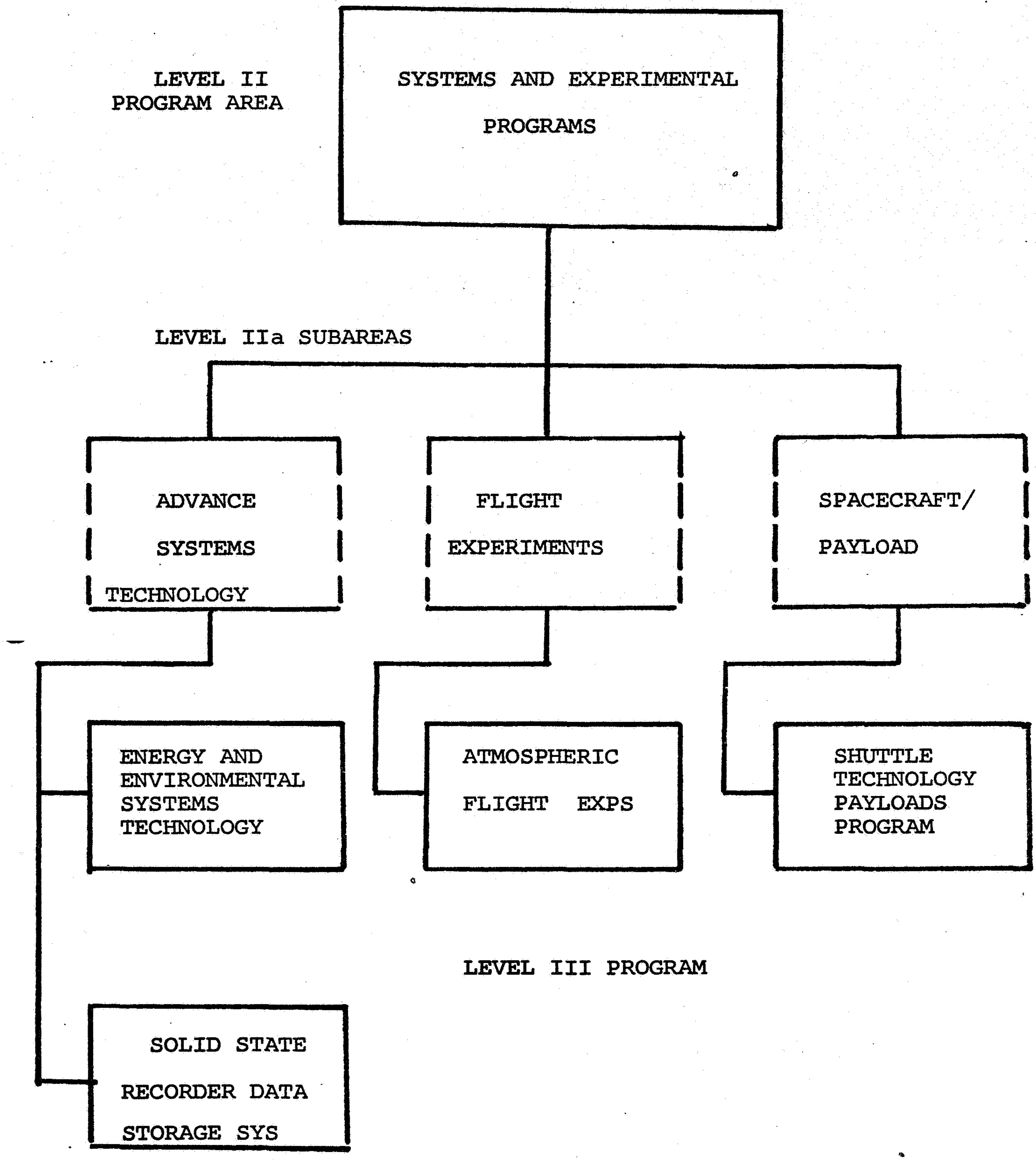
(3) Establish, for future missions, parametric trade-offs and sensitivities relating the level of technology in critical disciplines to various measures of flight program accomplishment--e.g., performance cost, benefits, etc.

(4) Recommend individual and integrated technology program goals on the basis of analyses such as those indicated above.

(5) Identify mission and design alternatives or opportunities on the basis of analyses such as those indicated above.

Targets are to be established during April 1974.

SPACE AND NUCLEAR WORK BREAKDOWN STRUCTURE SYSTEMS AND EXPERIMENTAL PROGRAMS, LEVEL II, IIa, AND III



Systems and Experimental Programs

PROGRAM AREA GOAL

The goal of systems and experimental programs is:

> Verify the technical readiness of a concept, so that when completed, the next logical step of the R&D process, development (advanced, supporting, or prototype) is possible; this is achieved through experimental testing and verification in a realistic environment and has as its thrust minimizing technical and economic risk with the expressed purpose of decreasing the excessively long time lag between application (initiation of development) and the demonstration of technical feasibility.

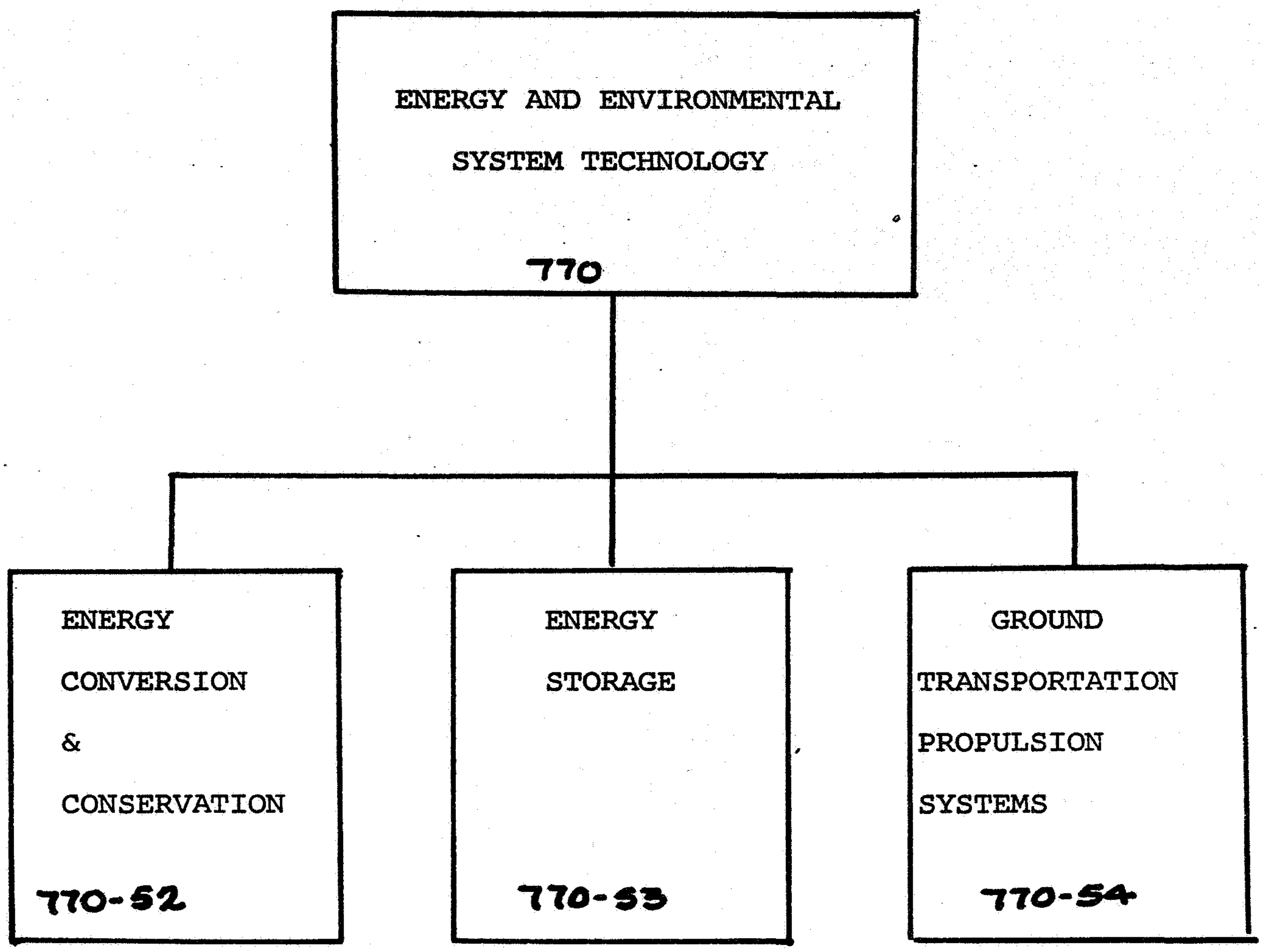
The programs conducted under this program area goal fall into the following classifications (subareas):

- o Advanced System Technology
- o Spacecraft/Payloads

These programs tend to be multi-disciplinary and are usually focused on well defined needs. The user is very often significantly involved in such activities. The systems and experimental programs focus on the practical aspects of applying the technology including consideration of the real world environment in which the technology must reside. Although this activity is pursued as a logical step in the research and technology process, the extent of OAST involvement is determined by special considerations of user needs, recognizing the advance technical developments that are funded by user offices such as OSS, OA and OMSF.

ADVANCED SYSTEMS TECHNOLOGY

Programs in this sub-area are multi-disciplinary and involve testing the concept in a realistic system environment. The key characteristic of activities in this sub-area is applicability to a great many needs and the necessity to verify the technical readiness of the concept in a realistic environment in order to acquire the needed confidence. The potential payoff of advanced systems technology is very great but cannot usually be established to the satisfaction of the user until the work is well under way.



LEVEL IV SPECIFIC OBJECTIVES

TITLE: Energy Conversion and Conservation

TYPE OF OBJECTIVE: ____ Discipline ____ Study

X System and Experimental Program

ORGANIZATIONAL ELEMENT RESPONSIBILITY: Energy and Environmental Technology Program/R. D. Ginter

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Reduce Stationary power plant fuel consumption and pollutant emissions by 25-40%. Specific Targets are:

- Demonstrate the practicality of high temperature gas turbines with inlet temperatures to 2500°F and associated low pollution combustion for use in advanced, high efficiency fossil-fuel central-station generating plants, and in high performance coal gasification plants.

- Demonstrate for OCR the technical and economic advantages (fuel economy, reduced cost of electricity and reduced environmental impact) of a fossil-fueled potassium topping cycle plant.

- Develop and experimentally validate an analytical model of the elemental processes of the combustion of coal in a fluidized bed.

- Assess the potential of MHD systems for use in power plant topping cycles and demonstrate the technology required for application of MHD systems.

- Demonstrate for EPA the effective operation of an industrial air pollution source identification system based on trace chemical constituents of airborne particulate matter.

- Assess the potential of low temperature energy conversion systems for use in conjunction with geothermal energy sources.

- Assess alternative energy conversion concepts to enable selection of promising approaches on the basis of impact and benefits to the nation and technology status.

Approach

The primary thrust of this program is directed to thermal energy conversion systems which will derive their heat from either coal or coal derived fuels. The one exception is the 275 MWe gas turbine test facility for HTGR and, even here, the facility will be adaptable to operation with a fossil fuel heat source. All work toward specific targets will be conducted jointly with other agencies (DOI, AEC, EPA) and in many instances substantial funding support will be obtained from those agencies.

Prior to actual committment to dedicated conversion hardware in any target area, comprehensive system evaluation studies will be conducted to assess system potential relative to other competing concepts. Concurrently, a strong materials development program will be pursued to obtain materials that will meet the environmental demands imposed by system development objectives. In addition, alternative combustion concepts will be investigated to explore their potential worth for the enhanced use of coal or coal derived fuels.

More detailed information pertinent to the major targets follows:

High Temperature Gas Turbine Program (HTGT)

The LeRC will direct an in-depth study to establish specific application requirements as they may influence the conduct of a development program for a high temperature (up to 2500°F) gas turbine with a low pollutant emission combustor. Development will be accomplished in a two-phase program. The first phase will provide for development of the requisite materials technology and the other constituent technologies for the aerodynamic components; the second phase will provide for fabrication and test of a complete rotating unit operating with the low pollution combustor in a laboratory test facility.

Major Milestones

- Complete application studies and critical technology definition for HTGT operation ------ FY-75.
- Complete system components technology development efforts ------ FY-78.

- Complete development of demonstration hardware ---- FY-79.

- Complete Test Program ----- FY-81.

Potassium Topping Cycles for Stationary Power

Under a NASA/OCR agreement the LeRC will manage a program to develop the technology requisite to commercial use of potassium topping cycles in plants generating up to 1200 MWe. This will include the integration of power conversion units with subsystems such as furnaces and fluidized bed coal combustors developed independently under the OCR R&D program. The effort will develop from a preliminary design and economic analysis now under contract to GE by LeRC for OCR. A pilot plant consisting of one potassium turbine of about 30 MWe capacity with its associated furnace/boilers and condenser/steam generators will be assembled and tested.

Major Milestones

- Complete preliminary design and economic assessment of commercial-scale potassium topping cycle plant ----- FY-75.

- Complete design for a pilot plant using potassium topping cycle ------- FY-75.

- Complete construction of pilot plant ----- FY-80.

- Complete testing of pilot plant ------ FY-82.

Analytical Model of the Combustion of Coal in a Fluidized Bed

The LeRC for the OCR will conduct an analytical and experimental program to define the elemental processes of the combustion of coal in a fluidized bed. The steps of the program are as follows:

1. The establishment of a preliminary analytical model of the process which represents the state of the art.

2. Using the state-of-the-art analytical model, design a definitive experiment to test the assumptions and approach used in formulating the preliminary analytical model. This will require the construction of a small fluidized bed combustor.

3. As a consequence of the comparison between the model and the experimental results, modify or recast the analytical model so that the physical phenomena are more faithfully predicted.

4. Where necessary, conduct another set of experiments designed to test the revised analytical model. Besides dealing with the underlying assumptions and parameters of the model, the experiment will include the important factor of scale. The comparison between experiment and analysis must be iterated until it is determined that reasonable agreement exists between the two.

This program will provide research support and data for use in design of larger scale advanced fluidized beds.

Major Milestones

- Complete design of small scale fluidized bed coal converter ----- FY-75.
- Develop physical/chemical sub area models --- FY-76.
- Construct fluidized bed test unit ----- FY-76.
- Test of integrated reaction model ---- FY-76.
- Verification of upgraded model ----- FY-77.

MHD Topping Cycle Program

The LeRC for OCR will investigate the technical and economic feasibility of a clean fuel MHD power generation system. LeRC will direct this effort which involves the design, fabrication, and testing of: A 0.2 MWe generator to verify power density, capability; a 5 MWt zero electrical output power MHD system test loop to demonstrate feasibility of components other than the MHD generator; a 5 MWe generator to verify enthalpy extraction capability; and a 50 MWe MHD channel facility to investigate various channel designs for alternative fuels and to demonstrate enthalpy extraction at high efficiency and long life.

Major Milestones

- Demonstrate short term operation (10 seconds) of a 0.2 MWe MHD generator with a power density of 100 W/CM^3 ---- FY-76.

- Complete systems study to determine earliest economic impact of 50-500 MWe generator ---- FY-76.

- Completion of high enthalpy extraction 5 MWe facility ---- FY-77.

- Completion of 5 MWt zero power MHD system component test loop ---- FY-78.

- Achieve enthalpy extraction of 20 percent with a 5 MWe generator ---- FY-78.

- Complete design of 50 MWe MHD channel facility ---- FY-78.

- Complete testing of 5 MWt zero power MHD system loop ---- FY-79.

- Complete construction of 50 MWe MHD channel facility ---- FY-80.

- Demonstrate enthalpy extraction greater than 20 percent at a MHD generator efficiency of 80 percent with greater than 1000 hour life ---- FY-82.

Pollution Source Identification Program

The LeRC in conjunction with the Ohio EPA and the City of Cleveland will continue to devise and test techniques for the identification of pollution sources by determining the distribution and relative concentrations of trace element and compound pollutants in urban environments. Measurements will be made in the Cleveland area and variations due to topographical, meterological and source conditions will be documented. This data will be used to define the minimum sampling effort required to produce statistically valid surveillance of trace elements and compounds in the atmosphere in order to establish potentially unique "fingerprints" which can be used to identify and locate individual sources of industrial pollution.

Major Milestones

- Carry out operational test of industrial air pollution source identification system ---- FY-75.

Gas Turbine Test Facility Program

This program will be conducted jointly with the AEC and is directed to provision of a facility for combined testing of a closed cycle Brayton conversion system generating 275 MWe for use with High Temperature Gas Reactors (HTGR).

The AEC has completed a conceptual design for the plant. Under the program plan, the AEC will contract for a preliminary plant design in early FY-75. Subsequently, NASA would construct the facility at Plum Brook Station to AEC specifications.

The AEC will be responsible for development of the High Temperature Gas Reactor. NASA would be responsible for conversion module fabrication, test and requisite enabling technology.

Major Milestones

- Conversion component fabrication complete ---- FY-78
- Test facility complete ----- FY-79
- Conversion component test and c/o complete ---- FY-81

Energy Conversion Alternative Study

The LeRC will direct a study to evaluate candidate energy conversion system alternatives on a common basis. The LeRC will establish a data base for use in energy conversion systems R&D programs. Candidate systems will include open and closed cycle gas turbines, supercritical CO_2, MHD, fuel cells and liquid metal, organic and steam rankine. The results of in-house technical evaluations and energy system assessment studies will be used to define future development programs.

Major Milestones

- Complete assessment studies and definition of developmental programs ---- end of FY-75.

Need and Relevancy

During the next several decades the electric utility industry in the U.S. must meet an urgent need to expand the supply of low-cost electrical energy with minimal impact on the environment. Just as important is the need to utilize our sources of fossil fuel efficiently and effectively to assist in meeting the National goal of self-sufficiency in energy. OAST experience in the development of technology for aeronautical and space propulsion systems is directly applicable to the problems of central station power generation systems. Technology in areas of energy conversion, materials and efficient, environmentally acceptable combustion of fuels is of primary relevance to the solution of problems associated with power generation.

a. Budget Resources

	FY-74	FY-75	FY-76	FY-77	FY-78	FY-79
Direct Manpower						
(Head Count)						
Manpower	16	61	56	57	73	73
Funding Requirements (K Dollars)						
Net R&D	580	400	1500	2500	3500	3500
IMS	259	575	200	200	200	200
Total R&D	839	975	1700	2700	3700	3700
R&PM Resources	980	830	1800	1800	2400	2400
Total Value	1819	1805	3500	4500	6100	6100
Reimbursables	2950	3600	10000	13600	8900	8900

b. RTOP Resources

		Negotiated FY-74		Best Estimates FY-75		FY-76	
Number & Title	Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power
770-18-01 Environmental Engr. & Energy Mgmt.	LeRC	470	13	320	60	1500	56
770-18-04 Tech. Applications To Environmental Problems	LaRC	110	3	80	1	---	--

TITLE: Energy Storage

TYPE OF OBJECTIVE: _____ Discipline _____ Study

X System and Experimental Program

ORGANIZATIONAL ELEMENTS RESPONSIBILITY: Energy and Environmental Technology Program/R. D. Ginter

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Facilitate the more effective use of existing energy resources by advancing technology and efficient and low cost energy storage systems.

Specific targets:

- Complete application studies required to validate suitability of selected energy storage technologies as a function of energy source and end use.
- Initiate analytical and experimental "proof-of-concept" programs to demonstrate feasibility for selected applications.
- Develop program plans for selected technology areas for FY 76 funding.

APPROACH:

NASA experience and capabilities are applicable to several important technology areas related to energy storage (e.g., electro-chemical, chemical and mechanical systems). Promising energy storage concepts will be identified and evaluated as to application potential. Relevant ongoing NASA projects will be reviewed and evaluated for expanded support. Analytical and experimental projects will be initiated in several areas where NASA potential for effective effort is particularly promising. The primary intent of the proposed program for FY 75 is to establish a firm technological and user-need basis to develop program plans for FY 76 funding.

Relevant technology competence established by LaRC, LeRC, and JPL in spacecraft control, power and thermal systems, structural analysis and design and electro-chemical systems provides a strong base for effective progress in selected energy storage areas. In particular, ongoing work in the Redox Flow Cell at LeRC, advanced batteries at JPL and the structural and materials capability of the LaRC for potential application to flywheel energy storage.

Major Milestones

- Complete applicability studies as a function of energy source and end use ------ 3rd Qtr FY 75
- Develop plan for NASA energy storage technology program ------ 3rd Qtr FY 75
- Complete feasibility demonstrations for selected applications ------ End FY 76

Resources

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Direct Manpower						
(Head Count) Manpower	1	6	12	12	12	12
Funding Requirements (K Dollars)						
Net R&D	84	400	500	500	300	300
IMS	16	50	100	100	100	100
Total R&D	100	450	600	600	400	400
R&PM Resources	38	225	225	225	225	225
Total Value	138	675	825	825	625	625
Reimbursables	--	--	200	500	500	200

b. RTOP Resources

Number & Title	Center	Negotiated FY 74 Net $ (K)	FY 74 Man-Power	Best Estimates FY 75 Net $ (K)	FY 75 Man-Power	FY 76 Net $ (K)	FY 76 Man-Power
770-18-01 Environmental Engr. & Energy Management	LeRC	--	--	125	2	200	6
770-18-04 Environmental Engr. & Energy Management	LaRC	84	1	75	2	100	4
770-18-xx Environmental Engr. & Energy Management	JPL	--	--	200	2	200	2

TITLE: Ground Transportation Propulsion Systems

TYPE OF OBJECTIVE: _____ Discipline _____ Study

_X_ System and Experimental Program

ORGANIZATIONAL ELEMENT RESPONSIBILITY: Energy and Environmental Technology Program/R. D. Ginter

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Develop and demonstrate environmentally acceptable propulsion systems for ground transportation which equal or better Federal Standards with improved fuel economy.

EPA/NASA Automotive Gas Turbine Program

Demonstrate, for EPA, an improved automobile gas turbine engine which meets the '76 pollution standards at reduced cost, size and fuel consumption. This Lewis Research Center program is to be completed by October 1975.

Hydrogen Injection for Automobiles

Demonstrate a hydrogen injected, internal combustion engine in an automobile which meets the '76 emission standards with a 20% increase in fuel economy. This JPL effort will be completed in late 1976.

Heavy Ground Transportation Systems

In FY 1975, complete application studies in support for DOT of Brayton, Stirling and advanced Diesel cycles for buses, trucks and trains. Define appropriate engine development programs.

Capability for Comprehensive and Consistent Evaluation of Alternative Ground Propulsion Systems

In cooperation with DOT and EPA, develop the capability in FY 1975 to perform comprehensive and consistent assessment of candidate alternative propulsion systems for ground transportation in order to provide objective and technically valid guidance to these agencies regarding feasibility and comparative potential benefits of proposed concepts.

Approach

Relevant capabilities for application to ground transportation propulsion systems are largely concentrated at the Lewis Research Center with a smaller, but significant capability at the Jet Propulsion Laboratory. The approach is to adapt the technology base and competence developed by these Centers in their aircraft gas turbine and space propulsion and power programs to the problems involved in developing more efficient and environmentally acceptable propulsion systems for a variety of ground transportation modes. This effort supports and is coordinated with the several Federal agencies having cognizance and responsibility for National transportation and environmental needs. As such, it is:

a. Focused on the assessment and evaluation of the feasibility of potential technical alternatives to assist user agencies in developing management plans and priorities.

b. The advancement of appropriate technology with the intent of carrying through to a sufficient state of maturity to establish commercial feasibility.

More detailed information relating to the specialized needs of the individual specific objectives follows:

Proposed Changes to Specific Objectives and Targets

NASA/EPA Automotive Gas Turbine Technology Program

Assist EPA in demonstrating a gas-turbine-powered vehicle which meets or betters the 1977 Federal Emission Standards with fuel consumption, driveability and cost competitive with comparable-sized internal combustion engine powered vehicles. This joint program is to be completed by Lewis Research Center by July, 1976.

Proposed Changes to Major Milestones

- Complete performance mapping and emissions test of baseline engine ------ Mid FY-74.
- Complete aerodynamic design-upgraded engine ----- Late FY-74.
- Complete tests on baseline engine aerodynamic components ------ Early FY-75.

- Complete road tests on baseline engine/'73 vehicle ----- Early FY-75.

- Delivery of upgraded engine ----- Mid FY-75.

- Complete tests on upgraded engine aerodynamic components ----- Mid FY-75.

EPA/NASA Hydrogen Injection for Automobiles.

The initial phase of this activity at the JPL is intended to provide a demonstration of technical feasibility using standard automobiles equipped with bottled hydrogen by mid-December 1973. A second and more intensive phase involves a cooperative program with the EPA and includes:

1. A detailed comparison of the performance characteristics of a standard automotive V-8 engine operating in its normal mode and the same engine adapted to operate on the products of a hydrogen generator.

2. A broad technology advancement program at the LeRC directed to investigation of alternative techniques for generation of hydrogen-rich gas from a variety of fuels.

3. The exploration of the feasibility of involving the automotive industry as active participants in the development and application of hydrogen injection technology to the automobile. An important objective for industry could be to adapt engine design and operating techniques for optimization of the overall performance with hydrogen injection.

4. Comparative tests of the V-8 engine adapted for efficient operation with lean fuel/air mixtures and operating on the products of a hydrogen generator.

5. Demonstration of a complete functional system by JPL in automobile road tests. System would demonstrate the integration of an on-board hydrogen generation system with a modified fuel induction and engine control system.

Major Milestones

- Completed Phase I program at JPL........Dec. 1973

- Define and negotiate NASA/EPA Interagency Agreement ......Late FY-74.

- Define and negotiate industry participation..Late FY 74
- Complete comparison tests of standard engine (with and without hydrogen generator)....Early FY 75
- Complete comparison tests of lean engine..End FY 75
- Demonstrate complete on-board system in automobile road tests.............Late FY 76

Heavy Ground Transportation Systems

The LeRC will continue to assist the DOT in the advancement of technology needed to meet efficiency, environmental and operational requirements for future bus, truck and train applications. This phase of the effort is focused on comparative studies of the Brayton and Stirling cycles in the 400 and 7500 horsepower range. Various forms of the Brayton cycle were studied in FY-73. A similar approach is being taken in FY-74 for the Stirling cycle, following which program recommendations regarding technology advancement efforts will be made.

Major Milestone

- FY-75 - Complete Stirling Engine Assessment Studies

Alternative Engines for Transportation

In conjunction with DOT and EPA, the LeRC will provide an evaluation and assessment capability which will allow selection of ground transportation systems which show promise of reducing fuel consumption by 25 to 50%; reduce demand on petroleum reserves through use of synthetic fuels, and meet or better Federal Emission Standards. It is the intent of this effort to provide a comprehensive analytical and experimental capability to assess and evaluate competing alternative ground propulsion systems on a consistent basis. This will provide valid and objective technical data for judgment by appropriate authority regarding user applications of competing transportation systems.

Selection will be made of several of the most promising concepts for demonstration.

Major Milestones

- Establish evaluation and assessment capability ----- Mid FY 75.

- Select candidate concepts for further evaluation; submit program proposals for management approval ----- Mid FY 75.

Need and Relevancy

Transportation consumes 25 percent of the Nation's energy; creates 60 percent of the atmospheric pollution and represents half of the National consumption of petroleum. The increased need for National transportation has been projected to triple within 50 years. Current and predicted petroleum shortages dictate that the technology for more efficient usage of fuel and alternate fuel systems be established. NASA, as one of the "high-technology" agencies has been asked by the President to help provide solutions to this problem.

OAST experience in the development of technology for aeronautical and space propulsion systems is directly applicable to the problems of ground transportation. Technology in areas of energy conversion, materials and the efficient and environmentally acceptable combustion of fuels is of primary relevance to the solution of ground transportation problems.

This proposed program is designed to fulfill three general requirements:

a. Reduce the energy consumption of transportation by developing high-efficiency, low-pollution propulsion systems;

b. Develop specific propulsion systems which can use a wide variety of fuels, particularly external combustion and gas turbine systems;

c. Develop and maintain propulsion-system evaluation and assessment capability to provide the authorities responsible for transportation "modal" and use decisions an objective, technically-valid perspective of the National propulsion system capability and realistic predictions regarding the benefits, availability and energy consumption of advanced propulsion systems.

Resources

a. Budget Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
Direct Manpower						
(Head Count) Manpower	43	49	30	30	30	30
Funding Requirements (K Dollars)						
Net R&D	1638	850	600	600	600	600
IMS	373	275	400	400	400	400
Total R&D	2011	1125	1000	1000	1000	1000
R&PM Resources	950	1250	960	960	960	960
Total Value	2961	2375	1960	1960	1960	1960
Reimbursables	565	1900	2000	1500	1700	1700

b. RTOP Resources

		Negotiated		Best Estimates			
		FY-74		FY-75		FY-76	
Number & Title	Center	Net $ (K)	Man Power	Net $ (K)	Man Power	Net $ (K)	Man Power
770-18-01 Environmental Engr. & Energy Mgmt.	LeRC	180	24	550	25	300	10
770-18-11 High-Efficiency Low Pollution Engine for Air	JPL	1433	20	300	20	300	20
770-18-10 Application Technology - Energy Management	FRC	25	1	-	4	-	-

SOLID STATE DATA STORAGE SYSTEM

New Start

Program Objective

Provide a modular, high density, no-moving-part, 10^8 bit solid state data storage system using magnetic bubble domain technology, and demonstrate the improved reliability and performance versatility of the system in tape recorder applications for aerospace vehicles.

Program Targets

The following major targets are established to accomplish the objective:

- By mid FY 76, complete 10^8 bit recorder design.
- By the end of FY 76, complete fabrication of engineering breadboard for laboratory evaluation.
- By mid FY 78, fabricate prototype hardware with 10^8 bit capacity for flight qualification.
- By late FY 78, complete flight qualification of the 10^8 bit solid state data storage system.

Program Approach

The solid state data storage project depends on successful synthesis of a 10^5 bit memory chip and a logic structure to provide input/output operations similar to those used in tape recorder systems. These activities are being pursued in the current technology program carried out at the Langley Research Center, and are due to be completed by mid FY 75.

Using the results from the above technology efforts, a two phase program will be initiated early in calendar year 1975. Phase I will include the design of a 10^8 bit solid state data storage system, fabrication of the basic memory elements, and construction and testing of the engineering breadboard system. Phase II will provide for the fabrication of a prototype data storage system, and the evaluation, test and qualification of the prototype system to flight standards. The program is separated into phases to insure that technical feasibility can be amply demonstrated prior to proceeding with the next step. Completion of this portion of the program by late FY 1978 is contemplated. Consideration of a flight experiment to demonstrate system operation in a real space environment will be initiated at the beginning of FY 1977 and is not a part of the current program plan. Langley Research Center will manage the procurement activities and the in-house evaluations of subsystems, breadboard system, and the flight hardware. Additional details are available in the Preliminary Project Plan entitled "Solid State Data System" submitted on January 29, 1974. Associated milestones are to be provided in the final Project Plan and Risk Assessment due in Headquarters on April 15, 1974.

NEED AND RELEVANCY

Data storage is a necessary function in most aerospace vehicles. The most cost effective technology currently available for performing on-board data storage function is the magnetic tape recorder which suffers severely from low reliability due primarily to its failure prone mechanical parts (over 70% of failures due to mechanical malfunction). Tape recorder reliability has been a matter of continuing concern to NASA because of its criticality to mission success, and a determined effort to develop technology for a no-moving-part, solid state data storage system has been carried on in the basic OAST technology program for the past decade. Recent developments in the relatively new technology of movable magnetic bubble domains has shown a strong promise for achieving the characteristics required of a solid state memory, i.e. high density storage, low cost (0.1 cents/bit), non-volatility, small size and weight, minimal power consumption, and high reliability (10 times better MTBF). The most important feature, high reliability, could be achieved since the bubble domain technology allows memory system design with no-moving-parts.

The Solid State Data Storage System program is undertaken by OAST to enhance the success of future space missions. The program has primary relevance to the specific OAST focus of "Lower Cost Performance - Effective Systems" providing technology for low cost exploitation of space. The program also has applicable relevance to "User Interactive Information Systems and Monitoring" and "Spacecraft and Entry System Technology" in the space matrix. Once a solid record of dependable performance and proven operating characteristics is demonstrated, the solid state data storage system is expected to find use not only in space applications, but in a variety of commercial applications as well.

RESOURCES

a. Budget Resources

	FY 75	FY 76	FY 77	FY 78	TOTAL
DIRECT MANPOWER (Head Count)					
Manpower	7	8	7	6	28
FUNDING REQUIREMENTS (K Dollars)					
Net R&D	750	750	400	-	1900
IMS	50	100	75	50	275
TOTAL R&D	800	850	475	50	2175
R&PM Resources	218	249	218	186	875
TOTAL VALUE	1018	1099	693	236	2996
Net Costs	200	700	600	400	1900

b. RTOP Resources

Since there is only one RTOP (750-51-01, LaRC) under this objective, resources are as shown above.

c. Crosswalk Analysis

1. 100% of resources of primary relevance to the specific OAST focus of "Lower Cost Performance Effective Systems."

2. 50% of resources of applicable relevance to "Spacecraft and Entry Systems Technology."

3. 50% of rresources of applicable relevance to "User Interactive Information Systems and Monitoring."

FLIGHT EXPERIMENTS

Programs in this sub-area aim at validating technological concepts through experimental flight testing in a realistic (sometimes actual) operational environment. This involves the design and fabrication of space flight hardware that undergoes atmospheric flight testing or forms a piggy-back experiment on an existing spacecraft.

ATMOSPHERIC FLIGHT EXPERIMENTS PROGRAM

Program Objective

Perform piloted atmospheric flight experiments to evaluate the flight characteristics, aerodynamic performance, handling qualities, and advanced control systems of the X-24B (hypersonic to lift/drag ratio (L/D) = 2.5) from Mach 1.5 to landing. The X-24B is characteristic of the double delta class of wingless aircraft with potential for future hypersonic military aircraft and advanced spacecraft. Satisfactory flight characteristics in the critical transonic speed regime will help to demonstrate the feasibility of the double delta wingless aircraft at these speeds.

Program Targets

Major targets for this program include:

- Complete glide flights (flight 5)--October 1973
- First powered flight (flight 6)--October 1973
- Complete subsonic performance evaluation--December 1973
- Complete transonic (M = 1.5) performance evaluation--February 1975

Program Approach

The program is a joint NASA/Air Force program and will be conducted in-house at the Flight Research Center. The X-24A airframe used in the now completed lifting body flight research program was externally modified by the addition of a pointed nose and side strakes to transform the vehicle into a higher performance double delta vehicle at minimum cost. Following completion of the X-24B in June 1973, the first glide flight was accomplished in August 1973 using B-52 air-launch techniques established in previous lifting body research. Using the same launch techniques, a series of powered flights will be made with the XLR-11 engine (engine used to power the X-1, faster than the speed of sound in 1947) at speeds of up to approximately Mach number 1.5. The program consists of 30 flights with both NASA and Air Force pilots participating.

NEED AND RELEVANCY

The X-24B configuration is representative of potential hypersonic military cruise aircraft and provides an opportunity to explore at low cost potential flight problems of this class of vehicle. Because the Shuttle also has a double delta planform, it is expected that X-24B flight information will be highly useful in prediction of Shuttle flight characteristics. Recent research at Langley, for example, has shown that the forward section of the wing (or fillet) is important to vehicle pitch-up characteristics and that double delta planforms may or may not have benign stall characteristics like a plain delta wing.

Program Resources

a. Budget Resources

	FY 73 & Prior	FY 74	FY 75	FY 76	FY 77	FY 78	TOTAL
DIRECT MANPOWER (Head Count)							
Manpower	40	45	45	45			175
FUNDING REQUIREMENTS (K Dollars)							
Net R&D	165	150	150	150			
IMS	558	628	628	628			
TOTAL R&D	723	778	778	778			
R&PM Resources	1,108	1,247	1,247	1,247			
TOTAL VALUE	1,831	2,025	2,025	2,025			
Net Costs		190	150				

b. RTOP Resources

Single RTOP No. 756-48-01 at FRC (resources shown as above).

c. Crosswalk Analysis

1. 100% of resources of primary relevance to the specific OAST emphasis on technology for military needs.

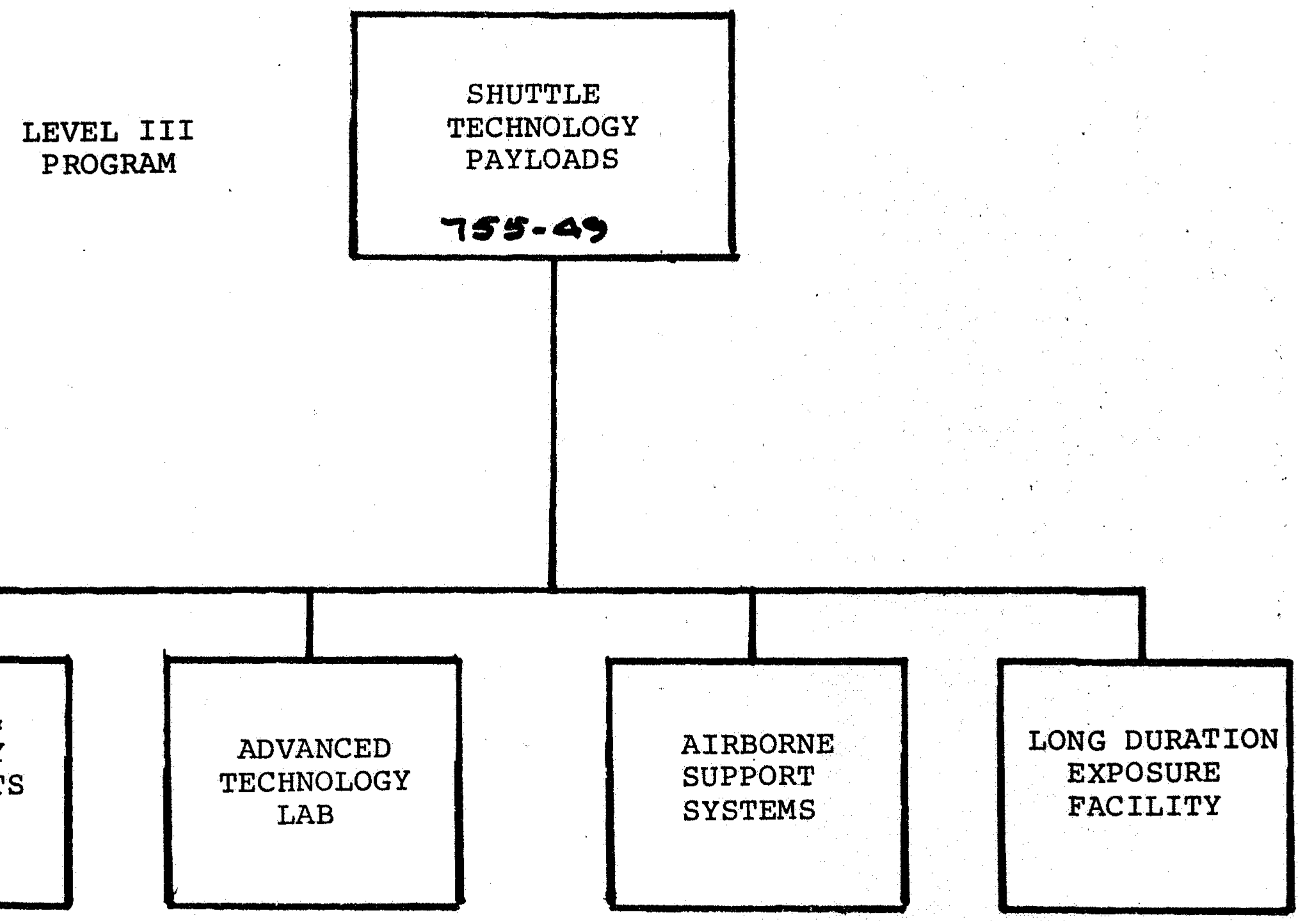
2. 100% of resources of applicable relevance to the OAST focus on lower cost and high performance effective systems.

SPACECRAFT/PAYLOADS

Programs in this sub-area involve the design, fabrication and testing of large to full scale research and/or experimental spacecraft payloads. Such spacecraft/payloads are often designed to become space facilities required to advance the state-of-the-art of the R&T disciplines, or to demonstrate technological systems. This activity can also include total spacecraft systems that aim at verifying theoretical and ground test results through demonstration of the system in the space flight operational regime and environment.

SHUTTLE TECHNOLOGY PAYLOADS PROGRAM

BREAKDOWN STRUCTURE   LEVELS III & IV



SHUTTLE TECHNOLOGY PAYLOADS PROGRAM

Program Objective

Develop technology, concepts, and space laboratory research facilities to enable OAST and other personnel to utilize the shuttle system capabilities in an economical manner to conduct research and technology investigations in space, where the attributes of the space environment are necessary for success of the investigations. The specific objectives of the program are:

- Development of an Advanced Technology Laboratory which will enable man to perform a variety of research and technology experiments in the space environment.
- Development of a Long-Duration Exposure Facility for long-term exposure in space of multiple passive experiments in order to evaluate the integrated effects of the space environment on materials and to devise methods for their alleviation.
- Preparation of Physics and Chemistry Experiments for Fundamental physical science investigations in Space.
- Definition and demonstration of an Airborne Support Program to evaluate during flight, with a simulation of the shuttle environment, the investigator/experiment/spacecraft interfaces during the payload development period and payload/spacecraft interfaces during operations.
- Definition of an Entry Technology Program for performing aerothermodynamic, materials and structures experiments using the shuttle orbiter as the test vehicle during nominal reentries.
- Development of an Integrated Real-Time Contamination Monitor to measure spatial and temporal contaminant distribution in the spacecraft/payload vicinity.

Exploitation of the shuttle system for advancement of research and technology development requires concepts appropriate to the radically new system capabilities, experiments tailored to provide the requisite information, and ancillary "facilities" that will accommodate payloads comprising many diverse experiments and assure their effective and efficient integration and operation. The Shuttle Technology Payloads Program is structured and scheduled to provide these needs in a time frame compatible with the potential shuttle operational era.

Program Resources

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	0	30	100	100	100	100

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
FUNDING REQUIREMENTS* (K Dollars)						
NET R&D	0	1800	4100	6300	7800	8200
IMS	0	200	900	1100	1200	1200
TOTAL R&D	0	2000	5000	7100	9000	9400
R&PM Resources		900	3800	3800	3800	3800
TOTAL VALUE		2900	8800	10900	12800	13200
EST. NET COSTS	0	1200	3500	6000	8100	9200

*Runout dollars FY 76 and beyond are subject to budget negotiation

TITLE: Physics and Chemistry Experiments In Space

TYPE OF SPECIFIC OBJECTIVE: ___ DISCIPLINE ___ STUDY XX SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Manned Space Technology Office - Mr. Hayes

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To define concepts for physics and chemistry experiments in space, to identify potential principal investigators for each experiment, and to conduct experiment definition studies for the more promising concepts. Specific tragets are:

- In FY 75 conduct preliminary studies to examine the potential and merits of space experiments in: Neutral and Ion Beam Chemistry; Fluid Physics Studies Dealing With Bubbles, Boiling and Drop Dynamics; and Flame Chemistry.
- In FY 76, solicit a broad segment of the scientific community and conduct additional studies as required.
- In FY 77, initiate experiment definition studies.
- In FY 78 and beyond complete experiment definitions studies.

APPROACH:

Major experiment studies (Feasibility Studies of Promising Stability and Gravity Experiments for Manned Orbiting Missions, EOS Report 7000, January 1966, Electro-Optical Systems, Incl.; Earth Orbital Experiment Program and Requirements Study, Report MDC G0680, December 1970, McDonnell Douglas, 13 Volumes; and Reference Earth Orbital Research and Applications Investigations, NASA Report NHB 7150.1, January 1971) have been conducted. A Physics and Chemistry Experiments Study Team and an Advisory Panel have been formed. The Study Team has conducted an in-house solicitation and some preliminary studies are being made in neutral and ion beam chemistry; fluid physics dealing with bubbles, boiling, and drop dynamics; and flame chemistry. The study team will solicit a broad segment of the scientific community for additional experimental concepts. Experiment definition studies will be made on the most promising concepts.

NEED AND RELEVENCY

In the near zero g environment of space many fundamental physics and chemistry experiments can be performed that are currently not feasible in the presence of the Earth's gravity. The Space Shuttle will offer a low cost transportation system to the space environment. Identification and definition of physics and chemistry experiments must be in initiated to be ready for shuttle flights in the 1980's.

RESOURCES:

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER						
Manpower	0	01				
FUNDING REQUIREMENTS* (K Dollars)						
NET R&D	0	325				
IMS	0	10				
TOTAL R&D	0	335				
R&PM Resources	0	31				
TOTAL VALUE	0	366				

TITLE: Advanced Technology Laboratory (ATL)

TYPE OF SPECIFIC OBJECTIVE: ____ DISCIPLINE ____
STUDY XX SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Manned Space Technology Office - Mr. Hayes

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: The objective is to utilize the Shuttle/Spacelab to provide a manned orbital research and technology facility in space and extend OAST ground based research and technology programs into space to exploit the unique characteristics of space.

By late FY 76 define the integration systems and equipment required for research and technology experiments to be carried by the Spacelab modular carrier.

By mid-FY 76 select research and technology experiments to equip a dedicated multi-disciplinary advanced technology payload.

By early FY 79 complete integration systems and support equipment design.

By the second quarter FY 81 integrate the experiment payload for the Spacelab and deliver to the launch site.

APPROACH:

The Spacelab is being designed and developed by the European Space Research Organization (ESRO). The Spacelab is planned to be a modular design and includes a habitable pressurized common support module, experiment support module, and a pallet (unpressurized). LaRC has correlated the LaRC space research activity as reflected in Research and Technology Operating Plans with studies of candidate experiments for manned space flight. Experiments have been identified in the disciplines of communications and navigation, earth observations, physics and chemistry, microbiology, component and system testing, and environmental effects. The ATL project at LaRC will define the integration systems and experiment support equipment required for multidisciplinary research and technology experiments to be carried aboard the Shuttle/Spacelab transportation system. The experiments will be integrated into the Spacelab experiment support and pallet modules at LaRC and mated to the pressurized common support module at KSC. The payload will be carried aboard the Shuttle into space on sortie (7 to 30 days) missions and returned to the Earth aboard the Shuttle. Close coordination with MSFC and the Spacelab development will be maintained to insure compatibility with the Spacelab carrier.

NEED AND RELEVANCY:

The Shuttle/Spacelab will provide the opportunity to make routine use of the unique characteristics of space - weightlessness, large vacuum sink, space radiation, and the unique location of space - to perform innovative research and technology in space that cannot be done on Earth or can be done more cost-effectively in space. This project will promote the timely development of the highest quality space technology, and demonstration of research and technology in space will augment the transfer of technology to users. Typical ATL experiments are: a Search and Rescue experiment to demonstrate the use of an orbital side-looking radar for detection and location of passive (RF) targets at earth emergency situations which potentially will save lives and reduce resources required for rescue and a Tunable Laser Experiment to demonstrate the utility of tunable lasers for global mapping of atmospheric constituents and pollutants which in conjunction with atmospheric mathematical models will provide better weather and pollution "episode" prediction capabilities. An orbital fatigue experiment will provide in situ data on the effects of the space environment on material fatigue life characteristics and fatigue cracks propagation.

RESOURCES:

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	0	10	40	40	40	40
FUNDING REQUIREMENTS* (K Dollars)						
NET R&D	0	575	1100	1240	2000	2000
IMS	0	75	400	400	400	400
TOTAL R&D	0	650	1500	1600	2400	2400
R&PM		310	1250	1250	1250	1250
TOTAL VALUE		960	2750	2850	3650	3650

*Runout dollars FY 76 and beyond are subject to budget negotiation

TITLE: Airborne Support Systems

TYPE OF SPECIFIC OBJECTIVE: ____DISCIPLINE____
STUDY XX SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Manned Space Technology Office - Mr. Hayes

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS

Objective: To define and develop a simulation of a Spacelab in an aircraft to demonstrate and test space technology shuttle payload experiments. Specific targets are:

In FY 75 design a Spacelab simulator

- o By end of FY 76, complete fabrication of Spacelab simulator and start installation in an aircraft
- o In FY 77, complete installation of Spacelab simulator and integrate first payload
- o By early FY 78, complete initial simulated sortie (7 day) flight with experiments and experimenters on board

APPROACH:

An aircraft of suitable size and performance (such as B-747, L-1011, DC-10, C-5) will be obtained on a lease basis and will be modified under contract to permit it to accept any combination of simulated Spacelab units (module and pallet sections) planned for Sortie missions. Actual missions will be flown with the entire complement of experiments scheduled for a Sortie mission, so that complete instrument systems can be tested and data can be gathered with the full participation of the experimenters.

NEED AND RELEVENCY:

The effectiveness of the Shuttle Spacelab Program will depend ultimately upon the degree to which the payload experiments operate successfully. A simulation of a Spacelab in a specially modified aircraft can provide a platform capable of accepting an entire complement of experiments together with the experimenters. This will allow experimenters to actually carry out their experiments during flight in a simulated mode.

RESOURCES:

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
MANPOWER	0	2				
FUNDING REQUIREMENTS*						
NET R&D	0	200	400	1500	1800	2000
IMS	0	20				
TOTAL R&D	0	220				
R&PM Resources	0	76				
TOTAL VALUE	0	296				

TITLE: Long-Duration Exposure Facility (LDEF)

TYPE OF SPECIFIC OBJECTIVE: ____DISCIPLINE____
STUDY XX SYSTEM AND EXPERIMENTAL PROGRAM

ORGANIZATIONAL ELEMENT RESPONSIBILITY:

Manned Space Technology Office - Mr. Hayes

STATEMENT OF SPECIFIC OBJECTIVE AND TARGETS:

Objective: To define and develop a Long-Duration Exposure Facility to expose more than 1300 square feet of passive experiments to the space environment for 6 to 9 months. Orbital deployment and retrieval will be by the shuttle. Specific targets are:

Complete final design by early FY 76.

Complete hardware fabrication by early FY 77.

Complete flight facility fabrication by fourth quarter FY 77.

Begin experiment/facility integration early FY 78.

Complete flight acceptance tests by end of FY 78.

Launch readiness early end of first quarter FY 79.

APPROACH:

LaRC and MSFC have jointly studied and defined a conceptual design for the LDEF, to provide feasible payload concepts for planning the design and development activity necessary to produce the LDEF. The facility is modularized and will accommodate 4-by 6-foot experiment trays carrying experiments relating to new materials, meteoroid protection configurations, solar cells, thermal coatings, sealants, microbes, seedlings, etc. Under the LDEF program the LaRC will design and build the facility and will integrate the experiment trays into the shuttle borne payload.

NEED AND RELEVANCY:

In past space flights the stringent limitations on payload size and weight and the general absence of recovery capability have severely limited in-depth evaluation of space environmental effects on materials, equipment, and biological samples. For example, the synergistic effects of the total space environment degrade thermal coatings differently than by exposing thermal coatings to an earth simulated space environment. Expanded knowledge relative to such effects is necessary in the planning of future space activities and is extremely desirable from the scientific viewpoint. The advent of the shuttle, with its capacity to economically transport bulky and heavy payloads to and from earth orbit, will permit acquisition of orders of magnitude more space exposure data than have heretofore been obtained. In addition, the LDEF payload is relatively uncomplicated and has undemanding orbital operations requirements, making it economical both to acquire and to use. The payload will be deployed during an early (developmental) shuttle flight (and would, therefore, save the expense of a special shuttle flight) and would be retrieved during a later flight.

RESOURCES:

	FY 74	FY 75	FY 76	FY 77	FY 78	FY 79
DIRECT MANPOWER (Head Count)						
Manpower	0	10	45	45	40	40
FUNDING REQUIREMENTS* (K Dollars)						
NET R&D	0	575	1400	1900	1800	1800
IMS	0	75	350	430	350	250
TOTAL R&D	0	650	1750	2330	2150	2050
R&PM Resources	0	300	1400	1400	1250	1250
TOTAL VALUE	0	950	3150	3730	3400	3250

*Runout dollars FY 76 and beyond are subject to budget negotiation